Livelihoods of Fulani pastoralists and burden of bacterial zoonoses in the Kachia grazing reserve, Nigeria

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Declaration

I declare that the research described within this thesis is my own work and that this thesis is my own composition and certify that it has never been submitted for any other degree or professional qualification.

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Abbreviations

2-ME	2-Mercaptoethanol Test
AB	Abortion
AGID-NH	Agar Gel Immunodiffusion with NH
AMOS-ERY	multi-locus AMOS PCR targeting the ery locus of *Brucella* spp.
ANOVA	Analysis of Variance
APOC	African Program for Onchocerciasis
ARC	Alliance for Rabies Control
ASV	Anthrax Spore Virus
AVO	Area Veterinary Officer
BP26	Brucella Protein 26
BTB	Bovine Tuberculosis
CBPP	Contagious Bovine Pleuropneumonia
cELISA	Complement Enzyme Linked Immunosorbent Assay
CFT	Complement Fixation Test
CFU	Colony Forming Units
CHT	Community Health Technician
CI	Confidence Interval
CIA	Central Intelligence Agency
CITA	Centro de investigación y tecnología agroalimentaria de Aragon
CLTS	Community Led Total Sanitation
COPP	Contagious Ovine Pleuropneumonia
CT	Card Test
CWEGSA	Cysticercosis Working Group in Eastern and Western Africa
D	Design Effect
DALY	Disability Adjusted Life Year
DANIDA	Danish International Development Agency
DEFRA	Department for Environment Food & Rural Affairs, UK
DF	Degrees of Freedom
DFID	Department for International Development
DGD-NH	Double Gel Diffusion with NH
DNA	Deoxyribonucleic acid
DRG	Disease Reference Group
Dse	Diagnostic Sensitivity
DSp	Diagnostic Specificity
EFSA	European Food Safety Authority
EU	European Union
F	Female
FAO	Food and Agriculture Organisation of the United Nations
FGD	Focus Group Discussion
FMD	Foot and Mouth Disease
FMEN	Federal Ministry of Environment of Nigeria
FP7	Framework Programme 7

FPA	Fluorescence Polarisation Assay
FPSR	False Postive Serological Reaction
FsRB	sRBT under field conditions
FTA	Fast Technology for Analysis
FUO	Fever of Unknown Origin
FWEC	Faecal Worm Egg Count
GALVmed	Global Alliance for Livestock and Veterinary Medicines
GDP	Gross Domestic Product
GF	Global Fund
GI	Gastrointestinal
GIT	Gastrointestinal tract
GPS	Global Positioning System
GSAPR	Government Structural Adjustment Programme Role
GsRB	sRBT under Government lab (Spain) conditions
HAT	Human African Trypanosomiasis
HG	Hygroma
HH	Household
HHH	Household Head
HIV/AIDS	Human Immunodeficiency Virus/Acquired Imminodeficiency Syndrome
HOOF	Hypervariable Octameric Oligonucleotide Fingerprints
HRW	Human Rights Watch
HSV	Haemorrhagic Septicaemia Vaccine
I	Inconclusive (BTB)
ICONZ	Integrated Control of Neglected Zoonoses
ID	Identification
IDF/WAMCO	Integrated Dairy Farm
IDMC	Internal Displacement Monitoring Centre
IDP	Internally Displaced People
iELISA	Indirect Enzyme Linked Immunosorbent Assay
IFRC	International Federation of Red cross and Red Crescent Societies
ILCA	International Livestock Centre for Africa
ILRI	International Livestock Research Institute
IQR	Interquartile Range
IRIN	Integrated Regional Information Networks
ISaBmS	Reference sera from goats infected with *B. melitensis*
KADP	Kaduna Agricultural Development Project
KAP	Knowledge, attitudes and practices
KGR	Kachia Grazing Reserve
KII	Key Information Interview
LA	Long Acting Antibiotic
LD	Livestock Development
LFA	Lateral Flow Assay
LG	Local Government
LGA	Local Government Area

LPS	Lipopolysaccharide
LSD	Lumpy Skin Disease
LVI	Local Veterinary Inspector, UK
M	Male
MACBAN	Miyetti Allah Breeders Association of Nigeria
MD	Medical Doctor
MDGs	Millenium Development Goals
MLSA-SNP	Multilocus Sequence Analysis-Single Nucleotide Polymorphism
MLVA	Multi Loci VNTR Analysis
mRBT	modified Rose Bengal Test
MRI	Magnetic Resonance Imaging
MRT	Milk Ring Test
MSB	Mean Square Between Clusters
MSW	Mean Square Within Clusters
MZCC	Mediterranean Zoonoses Control Centre
MZCP	Mediterranean Zoonoses Control Programme
N	Number
N	No
N	Nigerian Naira
NA	Not Applicable
ND	Not Done
NGO	Non Governmental Organisation
NH	Native Hapten
NIH	National Institutes of Health
NLPD	National Livestock Project Department
NLPU	National Livestock Project Unit
NmRB	mRBT under NVRI lab conditions
NPFS	National Programme for Food Security
NS	Not Specified
NsRB	sRBT under NVRI lab conditions
NTDs	Neglected Tropical Diseases
NVRI	National Veterinary Research Institute
NZDs	Neglected Zoonotic Diseases
OD	Optical Density
OIE	World Organisation for Animal Health
OIEISS	OIE International Standard Serum
OPS	O-polysaccharide
PABAK	Prevalance and Bias Adjusted Kappa
PARE	Pastoral Resolve
PAZ	People and Zoonoses
PCR	Polymerase Chain Reaction
PE	Participatory Epidemiology
PGE	Parasitic Gastroenteritis
PO	Project Officer

PPR	Peste des Petits Ruminants
PRA	Participatory Rural Appraisal
Px	Prophylaxis
R	Reactor (BTB)
R-LPS	Rough Lipopolysaccharide
RB	Reduced breeding
RB51	Rough *Brucella* vaccine
RBT SN	RBT with supernatant only
Rev1	Smooth *Brucella* vaccine for small ruminants
RID	Radial Immunodiffusion Test
RIU	Research into Use
RIV	Rivanol Test
ROC	Receiver Operator Characteristic
ROH	Rate of Homogeneity
RPT	Rapid Plate Test
S-LPS	Smooth Lipopolysaccharide
S19	Smooth *Brucella* vaccine for cattle
SAT	Serum Agglutination Test
SB	Stillbirth
SE	Standard Error
SICCT	Single Intradermal Comparative Cervical Test
SOS	Stamp Out Sleeping Sickness
sRBT	standard Rose Bengal Test
SSA	sub-Saharan Africa
TB	Tuberculosis
TB testing	Tuberculin Testing
TCRV	Tissue Culture Rinderpest Virus
TLU	Tropical Livestock Units
Tx	Treatment
UmRB	mRBT under UNAV lab conditions
UN	United Nations
UNAV	University of Navarra, Spain
UNDP	United Nations Development Fund
US	United States
USA	United States of America
USD	US Dollars
UsRB	sRBT under UNAV lab conditions
VLIR	De Vlaamse Interuniversitaire Raad
VNTR	Variable Number of Tandem Repeats
WAHID	World Animal Health Information Database
WC	Weak calf
WHO	World Health Organisation
Y	Yes

Glossary

baba	lumpy skin disease
bakale	brucellosis
boru	FMD
Bunaji	White Fulani cattle
dumaral	PPR or COPP
fufu	CBPP
goli	PGE
hanta	liver/fluke/clostrium noyi
jangali	cattle tax abolised in Nigeria in 1976
jewuro	household head
jonte	malaria
kindirmo	intermediate between butter and yogurt
kirchi	dermatophylosis
Ladduga	Fulani name for KGR
malewama-hanta	fluke
nebam	butter
nono	yogurt
nyamri	maize corn porridge
Rahaji	Red Bororo cattle
ruga	homestead
samore	Trypanosomiasis
sefa	anthrax
Tampol	market centre of KGR
tari	BTB
tarin puka	TB
wara	cheese
wuro	household
Zakat	Islamic almsgiving

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Abstract

The work presented focuses on bacterial zoonoses in northern Nigeria, and more specifically on brucellosis in the Kachia grazing reserve (KGR) - rangeland set-aside by the government to sedentarise Fulani pastoralists. The objectives of the study were to 1) undertake demographic and socioeconomic profiling of the KGR community; 2) review the evidence for brucellosis burden in Nigeria; 3) assess the suitability and performance of brucellosis diagnostic tests selected for use; 4) compare burden of brucellosis across different species (animal and human) and determine *Brucella* species present in KGR; 5) explore social or environmental factors which may promote or prevent brucellosis transmission; 6) make recommendations for brucellosis control in the KGR and Nigeria; 7) explore community perception of disease and determine household expenditure on animal health; 8) critically evaluate the system's, integrated, disease cluster, 'One Health' approach applied in this study.

Three surveys comprising animal (cattle, sheep and goat) and human sampling, administration of questionnaires, focus group discussions and key informant interviews were undertaken in March, June and October 2011. A population census was undertaken in June 2011. Comparison of 2010 government census data with June 2011 census data showed that a mass immigration event occurred in April-May 2011 as a result of post-election violence, with cattle and human populations increasing by 75%. Questionnaire and census data demonstrated the diversity and heterogeneity of the Fulani community in terms of wealth status (roughly corresponding to livestock assets), household size and composition and livelihood diversification strategies. While Fulani in grazing reserves were assumed to be sedentary, KGR households were found to practice wide-range dry and wet season transhumance. Cattle productivity parameters and herd dynamics were similar to those reported by other authors for the extensive pastoralist systems in the sub-humid zone. Herd increase over a one-year period was found to be low or negative for most households in this low input, low output system.

Brucellosis epidemiology in the KGR involves *B. abortus* biovar 3a with low individual and moderate cattle herd prevalence and occasional spill-over into small

ruminants. No human brucellosis was detected despite over 80% of the KGR population consuming raw milk and engaging in risky behaviours, raising questions about the potential lower virulence of the local biovar. Low infection rates in livestock, disease-reducing intuitive behaviours or immunity may also be at play.

The RBT was found to perform well under field conditions, despite poor concordance when applied in different laboratories and under different conditions. Prospects for control/elimination of brucellosis in the KGR are poor, but low animal burden and absence of human disease render vaccination uneconomic. A review of the literature in Nigeria suggests that brucellosis burden is higher in intensive livestock production systems, which should be targeted first. A laissez-faire approach to brucellosis control in the nomadic pastoralist domain may appeal to policy-makers, as interventions in migratory populations are difficult. Brucellosis is perceived by the KGR community as the number three-priority disease, after trypanosomiasis and *Fasciola gigantica*/clostridial infection and this was reflected in household expenditure on chemotherapeutics and prophylaxis.

Finally, the value of the One Health approach is the ability to see the whole picture, including disease impacts in the animal reservoir as well as the human population, without which erroneous epidemiological and economic conclusions may be drawn; for example, presence of brucellosis in the animal reservoir does not necessarily indicate presence of human disease. This work shows that moving from disciplinary silos to a more holistic or system's approach spanning epidemiology, evaluation of diagnostic and control tools as well as socio-economic, cultural and institutional aspects can lead to more appropriate recommendations for disease control.

1 Chapter 1 General introduction: the Neglected Zoonoses

1.1 Defining zoonoses, NZDs and NTDs

1.1.1 Zoonoses

Zoonoses are defined as those diseases and infections transmitted between vertebrate animals and humans. They are ubiquitous in nature, with 61% of all human pathogens being zoonotic (WHO, 2014) incorporating 868 pathogens (Taylor et al., 2001, Woolhouse and Gowtage-Sequeria, 2005). Zoonoses include a broad range of conditions caused by infectious agents (viral, bacterial, mycotic, chlamydial, rickettsial and parasitic pathogens) with diverse clinical and epidemiological features. Some, such as bovine tuberculosis and anthrax, can have a considerable impact on both human and animal health; some, such as zoonotic trypanosomiasis, have more impact on human health; others, such as Newcastle disease, can have devastating effects in livestock but are comparatively mild in humans (Schelling et al., 2007a).

1.1.2 Transmission

The mechanisms for zoonotic disease transmission are varied and may include direct transmission by aerosols or contact (as is the case for rabies through a bite), or indirect transmission via vectors (for example, sleeping sickness and Rift Valley Fever), or via food, water and fomites (for example bovine tuberculosis, cysticercosis and salmonellosis). Some diseases, such as brucellosis and Q fever have multiple routes of infection. Foodborne transmission of zoonoses is important, and it has been estimated that around two billion cases a year of human disease are caused by foodborne illnesses, the largest contributor to this disease burden consisting of animal-sourced foods; foodborne diseases affect almost half the world's population (Murphy, 1999).

1.1.3 Reservoir

Zoonoses can also be categorised depending on the degree to which animals act as a maintenance reservoir. In many cases, animals play an important role in maintaining the infection in nature. Of the 27 diseases listed in the WHO Global Burden of Disease DALY (disability adjusted life year) table for 1999 (WHO, 2000), 20 can be can

classified as zoonoses according to a strict definition of documented natural transmission between animals and humans (Coleman, 2002). Of these 20 zoonoses, 7 (Chagas disease, hookworm, hepatitis E virus hepatitis, Japanese encephalitis, leishmaniasis, schistosomiasis and trypanosomiasis) have an important animal transmission cycle, which presents an opportunity for tackling the disease through veterinary interventions.

1.1.4 NZDs

A sub-category of zoonoses, the 'neglected zoonotic diseases' or NZDs, and is the focus of this research. They are associated with the developing world where conditions for their maintenance and spread exist. NZDs originally included seven endemic zoonoses: anthrax, bovine tuberculosis, brucellosis, *T. solium* cysticercosis/taeniosis, cystic echinococcosis/hydatidosis, rabies and zoonotic human Africa trypanosomiasis, but now also include fascioliasis (and other foodborne trematodoses), leptospirosis, leishmaniasis, alveolar echinococcosis, and Rift Valley Fever (WHO, 2011).

1.1.5 NZDs, the poorest of the Neglected Tropical Diseases (NTDs)

The relationship between poverty and burden of disease for NZDs is well recognised and poor and underserved 'remote rural', 'marginalised urban' or 'peri-urban' populations, often bear a disproportionately high share of the disease burden. This characteristic, and the fact that NZDs are often under-diagnosed and under-reported, are features shared with the other Neglected Tropical Diseases or NTDs, of which the NZDs are a small subgroup. The NTDs (http://www.who.int/neglected_diseases/diseases/en/) incorporate 20 parasitic, bacterial and other conditions: Buruli ulcer, Chagas disease (American trypanosomiasis), cysticercosis, dengue/severe dengue, dracunculiasis (guinea-worm disease), echinococcosis, fascioliasis, human African trypanosomiasis, leishmaniasis, leprosy, lymphatic filariasis, onchocerciasis, rabies, schistosomiasis, soil transmitted helminthiasis, trachoma, yaws, podoconiosis, snakebite and strongyloidiasis (WHO, 2010). These ancient companions of poverty affect a billion people worldwide (referred to as the 'bottom billion' and who live on less than $2 per day) and threaten the health of millions more (Hotez and Kamath, 2009, Hotez et al., 2009, Hotez et al., 2007, Molyneux et al., 2005, Molyneux, 2008). All lead to long-term disability, which in turn

enhances or maintains poverty resulting from disfigurement or other sequelae of long-term illness, impaired childhood-growth and development, adverse outcomes of pregnancy and reduced reproductive capacity (Hotez et al., 2007).

The under-reporting of under-diagnosed diseases affecting under-served populations leads to underestimates of the global burden of these diseases, which translates into a lack of public or international interest and ensuing neglect at the global health arena (Boutayeb, 2007, Canning, 2006, Engels and Savioli, 2006, Holveck et al., 2007, King and Bertino, 2008, Mathers et al., 2007, May, 2007). NZDs have been described as the 'poor cousins of the poor cousins' (WHO, 2011); only 0.6% of international global assistance for health is devoted to the control of NTDs and the NZDs probably have a share of less than 10 % of that - 0.06% of the total (WHO, 2011).

1.2 The nature of neglect

The NZDs are 'neglected' for three main reasons:

1. Prioritisation relative to other diseases on the global health agenda,
2. 'The big three' (malaria, tuberculosis and HIV/AIDS);
    a. Diseases highlighted by the Millennium Development Goals (MDG) (malaria and HIV/AIDS);
    b. The emerging zoonoses with pandemic potential.
3. The political dimensions of prioritisation.
4. By virtue of their shared characteristics:
    a. The propensity for **under-diagnosis** and **under-reporting** which leads to paucity of reliable qualitative or quantitative data and ensuing underestimates or complete lack of burden estimates;
    b. Their association with poverty;
    c. Falling between veterinary responsibilities and medical needs;
    d. Their association with neglected livestock keeping population: livestock development has tended to be treated as the poor cousin of crop agriculture, receiving less financial support from donors and national government;

e. Poor and fragmented surveillance systems for collection of data on disease occurrence in domestic animals, wildlife and humans by veterinary, wildlife and public health sectors.

1.2.1 Domination of 'big three'

The MDGs (agreed by the United Nations in September 2000) incorporate 8 goals, including MDG 6, which aims to 'combat HIV and AIDS and other diseases' (UN, 2014). The Global Fund, an international financing institution has committed US$ 22.6 billion across 150 countries to support large-scale prevention, treatment and care programs against AIDS, tuberculosis and malaria (GF, 2014). Within MDG 6, the NTDs fall into the category of 'other diseases', which receive 0.6% of total international assistance compared with 37% for HIV/AIDS (Kirby, 2010).

The 'big three' dominate the global health agenda mainly because the WHO Global Burden of Disease (GBD) table (which quantifies and ranks the global and regional burden of diseases and is based on disability adjusted life year [DALY] calculations) reinforces the importance of control of HIV/AIDS, TB and malaria in delivering against the MDGs (Mathers et al., 2007). The GBD study provides a standardised measurement framework to allow comparisons across diseases and injuries (as well as risk factors), while the DALY is a time-based measure that incorporates years of life lost due to premature mortality and the equivalent number of years lived with disability or illness (Murray, 1994, WHO, 2008b). The big three were already in receipt of substantial sums from donors and post-MDG pledges and their high DALY scores and ranking on the GBD table led to corralling of donor funding allocations.

1.2.2 Criticism of the DALY

The over-emphasis placed on the DALY as a measure of burden of disease and as a benchmark for global-health priority setting, has been criticised by several groups of health economists. Mathers et al. (2007) recognise that there is a comparative lack of information available on NTDs, with fragmented and incomplete data on the epidemiology and risk factors of these diseases. Canning (2006) argues that overall

burden of disease should not be used as a criterion for priority setting and emphasises that if the goal is to maximise health benefits from a fixed health budget, then cost-effective interventions should be prioritised. King and Bertino (2008) state that the design of the DALY and its use in policy estimates contain inherent flaws (namely that they fail to acknowledge the context of burden for the poor and that disability weights are as a result underestimated in the presence of poverty). This results in systematic under-evaluation of the importance of chronic diseases such as the NTDs by the current DALY framework and an invalid system for determining health priorities.

1.2.3 Emerging zoonoses

Not all zoonoses are neglected; in fact, the emerging zoonoses have received considerable international attention and funding. Outbreaks of bovine spongiform encephalopathy (BSE), severe acute respiratory syndrome (SARS) and of influenza pandemics capable of crossing the species barrier are estimated to have cost the global economy at least $200 billion in terms of reductions in international trade and tourism (WHO, 2011). The 'rapid response/early detection agenda' has become a pre-requisite for governments, UN agencies, regulatory authorities and the pharmaceutical industry because of the propensity of emerging zoonoses for rapid pandemic spread, their association with intensive farming and their impact on international trade; characteristics which are of economic and public health significance worldwide but which reflect concerns originating primarily from the developed world to protect its population and economic interests (Cutler et al., 2010). This is in contrast to the NZDs, which do not pose a worldwide threat, are associated with humans living in close proximity to their livestock (first world livestock systems no longer involve such close human-animal contact) and have been eliminated or even eradicated from affluent parts of the world.

1.2.4 Political dimension

There is a lack of provider interest due to the negligible marketable opportunities presented by NZDs (Boutayeb, 2007). The perception of a disease as a threat to the trade and industrial interests of high-income countries or as a source of revenue for

pharmaceutical companies will have a motivational influence on donor funding (Ollila, 2005). NTDs and NZDs do not threaten the economies of industrialised countries so powerful interest groups have not mobilised around them (Maudlin et al., 2009).

1.3 Raising the profile of NZDs: momentum towards recognition

While several NTDs are celebrating landmark achievements towards 'overcoming' their global burden (WHO, 2010), the NZDs are still at the stage of gathering evidence of their true burden on society and building advocacy. There is significant commitment to raise the profile of NZDs and recognition of their importance to the health and wellbeing of humans and animals in poor communities is building. The First International Meeting on NZDs (NZD1), co-sponsored by the WHO and the UK's Department for International Development (DFID), took place at WHO's Geneva headquarters in September 2005. Researchers, policy-makers, public health practitioners and members of international organisations met to consider the relationship between poverty and a selection of endemic zoonotic diseases: the term neglected zoonosis was coined (WHO/DFID, 2006). The European Parliament recognised that NZDs had not received the attention they deserved from the EU (Boutayeb, 2007) resulting in consideration of NZDs at The European Technology Platform for Global Animal Health (http://www.etpgah.eu/). In 2005, the European Parliament adopted a resolution identifying a selection of NZDs and regretted the lack of research and development into diseases of the poor in developing (EU, 2005).

The Second International Meeting for Neglected Zoonoses (NZD2) held in November 2007 at the International Livestock Research Institute (ILRI) in Nairobi focused on applying the 'One Health' concept to achieve integrated control for the NZDs, with particular emphasis on Africa and policy issues (WHO, 2008c).

Since 2008, NZDs have become an integral part of WHO's Department of Control of Neglected Tropical Diseases and feature in the Global Plan to Combat Neglected Tropical Diseases 2008-2015 (WHO, 2010). In 2009 the WHO UNDP Special Programme established a Disease Reference Group on Zoonoses and Marginalised

Infectious Diseases (DRG6) to address, amongst other things, priority research issues in this field (Molyneux et al., 2011). OIE and FAO have also recognised the concept of NZDs and made commitments to dealing with them (WHO, 2011).

Sub-regional, regional and global disease-specific networks, programmes, alliances, working groups and public private partnerships have been established, including WHO's Mediterranean Zoonoses Control Programme (MZCP), the Alliance for Rabies Control (ARC), the Cysticercosis Working Group in Eastern and Western Africa (CWGESA), the Global Alliance for Livestock and Veterinary Medicines (GALVmed), Stamp out Sleeping Sickness (SOS) (WHO/DFID, 2006). Field and 'research and development' projects supported by major funding bodies (including DFID, RIU, the European Commission, the Bill & Melinda Gates Foundation, the Wellcome Trust, the NIH Ecology of Infectious Diseases Program, VLIR and DANIDA) have been commissioned, including, amongst others, the EU FP7 Integrated Control of Neglected Zoonoses (ICONZ) (http://www.iconzafrica.org/) and People, Animals and their Zoonoses (PAZ) supported by the Wellcome Trust (Doble and Fevre, 2010).

A third Neglected Zoonoses Meeting (NZD3) in November 2010 at WHO brought together a diverse group of participants, including policy-makers, international organisations, researchers and field workers and observers. Four themes emerged: the importance of under and miss-diagnosis; the role of community-based interventions for prevention and control; the need for evidence for cost-effectiveness of controlling the animal reservoir for human health benefits and the role public-private partnerships can play in addressing underfunding (WHO, 2011).

A fourth NZD meeting Advocay to Action was held at WHO in November 2014 which reviewed progress and made a series of recommendations http://www.who.int/neglected_diseases/zoonoses/fourth_international_nzd_meeting/en/.

1.4 Characteristics of NZDs

1.4.1 Summary of common characteristics which define an NZD

The characteristics of the NZDs are described below, as defined by the NZD3 expert consultation (WHO, 2011).

1. A **zoonosis;**

2. An **ancient** disease (which has successfully been controlled or eliminated in many wealthy countries);

3. A disease that imposes a **dual burden** on human and animal health, including significant economic losses;

4. A disease where transmission is dependent on **close relationships** and interactions between people, domestic animals and wildlife reservoirs;

5. **Control at source** is feasible (usually via the domestic animal reservoir) and presents opportunities for highly cost-effective interventions, and some of these diseases rank among the cheapest to control in terms of their 'dual' benefits (benefit to human health and improved livestock productivity and health);

6. Human and animal health sectors at provincial, regional and national levels usually fail to **prioritise allocation of funds** for the control of these diseases as medical officials believe that the responsibility lies with veterinary authorities and vice versa, hence these diseases often fall into the 'gap' between veterinary responsibilities and medical needs.

The following characteristics of NZDs are shared with other NTDs:

7. An **endemic** disease that for the most part does not spread rapidly and is confined to ecological boundaries with no potential for pandemic spread;

8. A tendency to be **clustered** in certain communities and amongst identifiable groups at risk, but understanding of epidemiology and geographic distribution (and geographic overlap of different zoonoses) is still poor;

9. Cause serious illness with significant **human morbidity and mortality** that can result in permanent **disability** and poor quality of life, or can be **fatal** if not dealt with early;

10. Cures exist which are relatively **inexpensive** if applied early;

11. Affect mostly poor, under-served and marginalised communities (i.e. they are diseases of **poverty**), particularly poor pastoralists, resource poor crop-livestock farmers or landless livestock keepers in urban and peri-urban sprawls;

12. These diseases are **under-diagnosed,** they are overlooked by clinicians or they require complex diagnostic capacity, or they are misdiagnosed because they share clinical features with more common diseases;

13. These diseases are therefore **under-reported** and this paucity of data leads to underestimates of their burden, or in some cases their burdens have never calculated at all, resulting in a vicious circle of lack of public or international interest which perpetuates their neglect;

14. Simple and relatively **low cost control strategies**, including health education, exist for the control of most of these diseases;

15. Cheap, effective bedside **diagnostic tests** are not always available.

1.4.2 Defining the link to poverty

1.4.2.1 Poverty as a risk factor for zoonotic disease

Poverty is a potential risk factor for zoonotic diseases. The poor, especially in rural settings, live in close contact with animals, promoting the opportunity for zoonotic infections. An example of this is reflected in the occupational exposure to bovine tuberculosis and brucellosis of pastoralists, highlighting the association between traditional production systems and these diseases (Cleaveland et al., 2007, Moda et al., 1996, Unger et al., 2003b, Unger et al., 2003a). The zoonotic reservoir can include domestic animals as well as wildlife, as is the case for anthrax (Clegg et al., 2007; Turnbull et al., 1991) (Clegg et al., 2007, Turnbull et al., 1991).

But the risk extends beyond livestock keepers to other members of poor communities, such as labourers working with livestock, butchers, traders (Donham, 1985) and consumers of livestock products (Swallow, 2000). Marginalised, remote and poverty-stricken communities usually have low standards of education and public services (both in terms of veterinary and public health infrastructure), and the poor often buy and sell

livestock products in informal markets, which increases the risk of transmission through milk and meat to the consumer (Bhatia, 1991). Cysticercosis, illustrates this point: meat that contains cysticercosis nodules is sold off cheaply without meat inspection and therefore preferentially purchased by the poorest consumers (Sikasunge et al., 2007). The negative impact of poor food standards for the production of cheap meat (and by default exclusion from high-value sanitary food markets) has health and financial repercussions all the way through the value chain, including impact on traders, processors and retailers of meat products (Murphy, 1999).

The poor will sometimes eat the carcases of dead animals as the meat is too precious to waste and can contract diseases such as alimentary anthrax (Sirisanthana and Brown, 2002, Sirisanthana et al., 1988). Poverty is also associated with insanitary living conditions and this increases the risk of water and foodborne infections (Marquis et al., 1990, Skidmore, 1999). The sale of raw or sour milk ruminant milk can increase exposure to diseases of bacterial (like brucellosis, tuberculosis, salmonellosis, listeriosis), viral (like hepatitis, foot-and-mouth-disease), rickettsial (Q-fever) or parasitological (toxoplasmosis, giardiasis) origin (Hempen et al., 2004).

1.4.2.2 Human burden and the cycle of poverty

Once infected, the poor have reduced opportunities for successful treatment, leading to disabling conditions and inability to work. A burden is also imposed on impoverished families who have to look after a sick family member, pushing them further into poverty while the death of a breadwinner can have devastating effects on household income (Kristjanson et al., 2004). Diseases such as sleeping sickness, anthrax, brucellosis and tuberculosis are more common in active adults (through occupational exposure amongst other factors), impacting on cattle-keeping households (WHO/DFID, 2006). Poverty is also a consequence of ill health (Braveman and Gruskin, 2003); the lower the income, the greater the likelihood of multiple zoonotic infection (Perry et al., 2002).

1.4.2.3 Impact on animals

The 'burden' of zoonoses in poor communities extends beyond human health to their impact on domestic animals. Brucellosis, for example, affects livestock productivity by reducing fertility, milk production, weight gain etc. (Mangen et al., 2012) and anthrax, can devastate herds through high mortality (Beyer and Turnbull, 2009, WHO, 2008a). Animal losses have a proportionally greater impact on poor people, who have fewer alternative resources or assets (Schelling et al., 2007a). There are an estimated 500-900 million poor livestock-keepers worldwide (Thornton et al., 2002, WHO/DFID, 2006) and livestock contribute to the livelihoods of at least 70% of the world's rural poor (LD, 1999). Livestock are often the only asset of pastoralist households and are central to their survival strategies (Delgado et al., 1999). Sale of animals can provide funds for emergency expenditure (school fees, food in times of shortage, or hospital fees). Small stock (sheep, goats and poultry) or sale of milk and eggs are a vital source of income for women and children (Quisumbing et al., 1995, Valdivia et al., 1996).

Households burdened with zoonotic diseases and who have suffered livestock losses as well as human disease also exhibit reduced coping capacity. They have increased expenditure for treatment of sick people and animals, but will have fewer resources to cover these costs through loss of livestock assets. Poor people keep fewer animals making them more vulnerable to an animal's disease or death. Livestock can push people into or pull people out of poverty (Schelling et al., 2007a). While livestock are essential for rural communities in terms of providing a protein and food source, beneficial to health as well as a source of income (Neumann et al., 2003), they can also have a negative influence on human and animal health through increased risk of zoonotic disease acquisition (Cleaveland et al., 2007).

1.4.2.4 Rural versus urban communities

While rural communities traditionally live in close proximity with domestic animals and therefore to be at increased risk of zoonotic infection, livestock production has recently expanded to the slums of urban and peri-urban zones in developing countries, presenting

an additional setting for the occurrence of zoonoses (Makita et al., 2008). Urban settings are increasingly important for dog-transmitted zoonoses such as rabies (Cleaveland, 1998) and echinococcosis (Acosta-Jamett et al., 2010).

1.4.3 Under-diagnosis and under-reporting

1.4.3.1 The 'undiagnosed'

Under-diagnosis of NZDs results from inherent difficulties in their diagnostics and fact that they tend to occur in communities that are often beyond the reach of formal health facilities. Access to diagnostics or treatment may be compromised due to absence or distance of health services or an inability to pay for them so that some sick individuals will never even seek medical attention (Liu et al., 2008, WHO/DFID, 2006).

1.4.3.2 Difficulties and delay in diagnosis

If patients are able to access health facilities, they may face multiple barriers and delays to being accurately diagnosed, since the capacity of rural health centres is often limited in terms of medical expertise and resources.

1.4.3.2.1 Lack of general expertise and poor knowledge of NZDs

Medical practitioners in rural areas may often not be qualified medical doctors, but rather 'environmental health technicians' without the professional capacity to conduct a thorough investigation. Even qualified doctors may have a low index of suspicion for many NZDs, partly due to the limited attention dedicated to these diseases in the curricula of medical schools. A study conducted amongst hospital staff in Tanzania found their knowledge of zoonoses to be poor (Kunda et al., 2008). Odiit et al. (2004) showed that for HAT, the delay in diagnosis of patients was due to diagnosis failure by service providers, with 77.4% of patients presenting to local sleeping-sickness hospitals doing so on their own initiative or on the recommendations of community members. Bukachi et al. (2009) found that 72% of HAT cases received their first appropriate diagnosis and treatment for HAT cases only in the late stage of the disease. This has major implications for disease prognosis since the earlier HAT is diagnosed, the better

the prospects of a cure. The failure of health providers to diagnose NZDs promptly is evident from a hospital-based study in which 4 children out of 133 patients were not diagnosed as having rabies until post-mortem examination (Mallewa et al., 2007).

1.4.3.2.2 Material limitations to diagnosis

Primary care centres are rarely equipped with the appropriate diagnostic equipment or the resources (e.g. microscopes, ultra-sound scanners, MRI machines, or laboratory reagents and consumables to conduct serological tests or cultures) necessary to attempt a comprehensive investigative work-up. Definitive diagnoses of neurocysticercosis, or echinococcosis, depend on access to imaging facilities (Singhi, 2011); only available (if at all) in a referral hospitals or tertiary healthcare centres of resource-poor countries (Del et al., 2012). Bovine tuberculosis and human tuberculosis may show similar clinical presentations but require different treatment regimes. Hospitals rarely have the expertise or facilities to run cultures to differentiate the two forms, resulting in all TB patients being treated with drugs for *M. tuberculosis,* which are not effective if the patient is infected with *M. bovis* (Cosivi et al., 1995, WHO/FAO, 1994). For some NZDs there may not be any reliable or cheap diagnostic tests available. The simple screening test used for the chronic, non-zoonotic form of HAT for example, does not work for zoonotic trypanosomiasis (Wastling and Welburn, 2011).

1.4.3.3 Healthcare seeking

There are many studies exploring healthcare seeking, exposing the prolonged, painful and expensive process which many individuals suffering from NZDs must go through before obtaining a definitive diagnosis and finally being successfully treated (Bukachi et al., 2009, Kunda et al., 2007, Odiit et al., 2004, Sindato et al., 2008).

1.4.3.4 Over diagnosis of malaria

One of the factors contributing to the delay in accurate diagnosis and treatment for NZDs is misdiagnosis for more common conditions such as malaria, as a result of shared syndromes (Animut et al., 2009, Reyburn et al., 2004). Sleeping sickness, brucellosis,

leptospirosis, rickettsiosis and Q fever for example, can all present as non-specific febrile illnesses that can be misdiagnosed as malaria. This not only results in misdiagnosis of NZDs but also in over diagnosis of more common conditions such as malaria. This is costly to health systems since prescribed drugs will not cure the patient, and whose condition will persist and who will then repeatedly seek medical attention. This is more critical with the recent introduction of anti-malarial drugs that are more expensive and toxic than traditional (but failing) mono-therapies (Amexo et al., 2004). A study in central Sudan demonstrated a rate of false-positive diagnosis of malaria of 75.6%; in contrast to the false-negative diagnosis rate of 0.01% (Elgayoum et al., 2009). Rabies is also misdiagnosed as malaria, with 11.5% of fatal central nervous system cases originally attributed to cerebral malaria being due to rabies (Mallewa et al., 2007).

1.4.3.5 Poor reporting of NZDs by human health and veterinary sectors

The limitations to obtaining a diagnosis, experienced by medical professionals, are shared by their veterinary counterparts. Poor livestock keepers rarely have access to veterinary services with the capacity to diagnose and treat their animals and cases of zoonotic disease in animals are rarely reported to public health authorities. Poor record keeping and surveillance across veterinary and human health sectors in developing countries leads to a lack of data and inaccurate disease reporting. Incidence and burden estimates seldom reflect NZD impact (Roger et al., 2004, Rumisha et al., 2007).

1.5 Estimates of burden of disease for NZDs

Studies that have calculated a DALY figure for an NZD, captured the full societal impact of zoonoses or conducted a cost-effectiveness analysis for a zoonotic disease control measure are reviewed in Table 1. To date, DALYs have been calculated for 3 NTDs: HAT, rabies and echinococcosis. Studies reflecting the full societal impact of disease (either at a global or regional level) exist only for brucellosis, rabies, echinococcosis, and cysticercosis. All control interventions listed in the table are within WHO's second most cost-effective band of less than US$150 per DALY averted and most are under the highly cost-effective band of US$25 per DALY averted.

NZD (Pathogen)	**Geographic focus**	**Approach**	**DALYs** or (*DALYs averted)*	**Cost of NZD (US$)** or (*Benefits in US$)*			**Intervention costs**	**Intervention cost-effectiveness** **(US$ per DALY saved)** *(Benefit cost ratio)* *(Net present value in $)*	**Reference**
				PH	**Animals**	**HH**			
HAT (*Trypanosoma brucei rhodesiense* and *Trypanosoma brucei gambiense*)	Global (> 95% burden occurs in Africa, rest occurs in Eastern Mediterranean region)	Databases; information provided by WHO members states (population-based epidemiological studies, disease registers and notification systems) No distinction made between 2 forms of HAT and assumed average 5 year duration of disease with 100% case fatality	1,335,075 (3% time discounting & **uniform** age-weights)	ND[2]	ND	ND	ND	ND	GBD 2002 (WHO, 2004)
HAT (*Trypanosoma brucei rhodesiense* and *Trypanosoma brucei gambiense*)	Global (see above)	Databases; information provided by WHO members states (updated country-level mortality estimate from 2002 study)[1]	1,673,075 (3% time discounting and **non-uniform** age-weights	ND	ND	ND	ND	ND	GBD 2004 (WHO, 2008b)
HAT (*Trypanosoma brucei rhodesiense)*	Tororo, Uganda	Decision-tree (under-detection) model and deterministic (subset) model	Under-detection method used to assist in calculation of DALY above	ND	ND	ND	ND	ND	(Odiit et al., 2005)
HAT (*Trypanosoma brucei rhodesiense)*	Serere, Uganda	Collection of field data (age, severity, level of under-detection and duration of hospitalisation) during an outbreak; calculation of empirical estimates of burden; modelling of under-reporting; intervention: hospital-based	1,157 (based on 69% under-reporting, 3% time discounting and uniform age weights)	4,312 (drugs per year) 7,649 (hospital costs per year)	ND	ND	11,961 (hospital based intervention + drug costs) 147/case	8.06	(Fevre et al., 2008)
HAT (*Trypanosoma brucei rhodesiense)*	Urambo District, Tanzania	Health centre records to capture data on direct and indirect costs to patients and health service.	979 (based on 45% under-reporting, 3% time discounting and uniform age weights)	11,841	ND	3,673 (hospitalisation costs) 9,781 (indirect non-medical costs)	ND	ND	(Matemba et al., 2010)

HAT (*Trypanosoma brucei gambiense*)	Buma, Democratic Republic of Congo	Field surveys: questionnaires and household survey (verbal autopsies and questionnaires); comparing of current control strategy (repeated active population screening and treatment) with situation had no intervention taken place	2145 (based on 40% under-detection, 3% time discounting, non-uniform age weights)	ND	ND	164/HH	24,020 301/case	17	(Lutumba et al., 2007)
HAT (*Trypanosoma brucei gambiense*)	Democratic Republic of Congo	Probability decision tree; intervention: population screening using lymph node palpation +/-card agglutination tests	ND	ND	ND	ND	ND	125 per life saved (CATT) 517 per life saved (LN) 452 per life saved (CATT + LN)	(Lutumba et al., 2005)
Brucellosis	Mongolia	Household surveys, Delphi study, WHO class II disability weight assigned; human to animal transmission model to simulate intervention (mass vaccination of cattle and sheep) outcomes	*61, 070* *(average number of DALYs averted by intervention with 52% protection and 5% discount rate)*	*BENFITS*	*BENEFITS* *26.6 million*	*BENEFITS*	8.3 million over 10 years	19.1 (considering public health contribution of 11%) 71.4 (considering public health contribution of 42%) *18.3 (NPV)* *3.2 (B-C ratio)*	(Roth et al., 2003)
Alveolar and cystic echi.	Tibet	Population-based prevalence study to construct DALY; disability weight of liver cancer of different stages; costs of disease in all sectors; intervention: deworming of dogs and vaccination of sheep and goats	Calculated for DALYs saved estimate		218,676 (livestock liver losses only) - ~1,000,000 (all livestock losses)		56,000 per year	78.35-164.77 (lower and upper limits, five-month *E. multilocularis* life span) 10.15 (to public health sector if cost-sharing implemented, five-month *E. multilocularis* life span)	(Budke et al., 2005)
Cystic echi.	Global	Databases and modelling to adjust for under-reporting; available literature on costs	285,407 (no under-reporting) 1,009,662 (accounting for under-reporting)	193,529,740 (no under-reporting) 763,980,979 (accounting for under-reporting)	141,605,195 – 2,190,132,464	Incorporated into total for PH	ND	ND	(Budke et al., 2006)

Rabies	Global	Based on up-to-date (at the time) WHO estimates of rabies deaths with consideration of age and sex distribution of cases	1,160,000	ND	ND	ND	ND	ND	(Coleman et al., 2004)
Rabies	Africa and Asia	Probability decision tree on development of disease after dog bite developed by Cleaveland et al. (2002) and sources of age-related dog-bite injuries; DALY due to deaths and post-exposure reactions; costs of livestock sector also assessed	1,740,000 (+ additional 0.04 million following side-effects of nerve-tissue vaccine)		583,500,000		ND	ND	(Knobel et al., 2005)
Cysticercosis (*Taenia solium)*	Eastern Cape Province, South Africa	Comprehensive assessment of the monetary burden on the health and agriculture sectors using decision tree analysis	ND		18,600,000-34,200,000		ND	ND	(Carabin et al., 2006)
Cysticercosis (*Taenia solium)*	Cameroon	Decision tree analysis constructed to estimate proportion of population with epilepsy due to NCC; estimate of losses due to porcine cysticercosis made on basis of various assumptions; standard methods used for DALY calculation.	45,838		10,255,202 Euro		ND	ND	(Praet et al., 2009)

Table 1 Review of studies which have calculated a DALY figure for an NZD, conducted burden assessment and/or evaluated the cost or cost-effectiveness of an intervention (Adapted from Schelling et al., 2007)

[1] Improvements made in methodology, based on critique of Fevre et al. (Fevre et al., 2008b) to consider calculation of separate incidence estimates for two forms of HAT and separate case fatality rates for treated and untreated scenarios. Quantification of under-reporting defined by Odiit et al. (Odiit et al., 2005) was also taken into consideration

[2] ND- Not done

1.6 Opportunities for the control of NZDs

Broad concepts around control of NZDs include the 'added value' of control measures (integrated, inter-sectoral, interdisciplinary, parallel, holistic or 'One-Health') and community-based and participatory interventions.

1.6.1 'Added value' of zoonosis control

Controlling NZDs present opportunities for 'added-value' on many levels.

1.6.1.1 Integrated interventions

Delivery of 'parallel' or integrated intervention packages to communities that incorporate a cluster of diseases may be more cost-effective than a vertical, single disease approach (Brady et al., 2006). Cost-effectiveness of integrated surveys for the NTDs was explored in Kolaczinski et al. (2010). Integrated control of NZDs and NTDs is feasible, as the diseases tend to be geographically clustered. However, the intuitive appeal of integrated control still requires evidence to confirm or refute the assertion of 'added-value' (Kolaczinski et al., 2007). A means of rapid identification of communities at highest risk of co-morbidity, determination of appropriate and sustainable delivery systems and approaches for integrating interventions into setting-specific packages are still required (Lammie et al., 2006).

1.6.1.2 Trans-disciplinary approach

A trans-disciplinary approach can offer added value, incorporating control strategies in the human and the animal reservoir to target all opportunities for transmission and thereby maximise the potential for elimination of disease (Welburn, 2011).

1.6.1.3 Inter-sectoral control

Added value may refer to inter-sectoral control efforts, with public health and veterinary sectors sharing financial responsibility for interventions.

1.6.1.4 Human benefits of animal interventions

One-Health principles extend to the broader human benefits of animal interventions for NZD control, where treating the animal reservoir presents a cheap and effective control strategy (Cleaveland et al., 2006, Welburn et al., 2006, Zinsstag et al., 2007).

1.6.1.5 Holistic health

Added value may come from a 'system's' or 'holistic' approach, where animal, human and ecosystem health are tackled simultaneously. The appeal for remote communities such as pastoralists, where there are only limited opportunities to administer an intervention, is obvious. An 'holistic health' approach offers the rationale for delivery of intervention packages that could include: simultaneous vaccination of children against measles; vaccination of livestock against brucellosis and/or anthrax; vaccination of dogs against rabies and community education on the risks of zoonoses transmission. In this way, economies of scale are promoted, as gaining access to marginalised communities is often the more costly component of the overall control cost (Kolaczinski et al., 2010).

1.6.2 Community-based interventions

Community-led approaches offer compelling and cheap opportunities for disease control for poor, marginalised and neglected populations. The rationale is that families and communities are empowered to take responsibility for aspects of disease control. Examples include the African Program for Onchocerciasis Control (APOC) in which communities make decisions and implement and monitor mass drug administration programs (Dadzie, 1997). Another example is Kamal Kar's Community Led Total Sanitation (CLTS), which aims to mobilise communities to completely eliminate open defecation, which can have an impact of faeco-oral transmission of diseases such as porcine cysticercosis (Harvey, 2011) (http://www.communityledtotalsanitation.org/).

1.6.3 Cost-effectiveness of zoonosis control

1.6.3.1 High DALY estimates

NZDs control provides a cost-effective opportunity for poverty alleviation since DALY estimates for these diseases tend to be high and benefits in terms of DALY's averted can also be favourable. This is for 3 reasons, firstly correction of DALYs for under-reporting and under-estimation reflects their true importance; secondly, a number of NZDS, such as neuro-cysticercosis are severely disabling, and can be attributed high disability weights; and finally, most NZDs are prevalent amongst children (rabies) or economically active adults (cysticercosis, HAT), resulting in high age weightings. The use of age weighting of DALYs is however still controversial (Barendregt et al., 1996, Paalman et al., 1998).

1.6.3.2 High monetary benefits to human health

Monetary benefits to human health can be high, because the price of some treatment regimes for cases of NZDS can be elevated. Rabies post-exposure prophylaxis of good quality can cost US$75 and treating late stage sleeping sickness costs US$800. Hydatid cyst removal can cost thousands of dollars. Preventing these diseases will eliminate these costs to the health services and to the patient (WHO/DFID, 2006).

1.6.3.3 Monetary benefits to animal health

The monetary benefit for livestock keepers for treating NZDs varies. The impact of zoonoses in dogs is hard to quantify as their economic value is hard to rationalise but NZDz affecting livestock do have quantifiable impacts on productivity and can provide evidence for the dual benefit of zoonosis control (WHO/DFID, 2006).

Costs of controlling NZDs can be relatively low for four reasons. 1. NZDs have been mostly eliminated or controlled in developed countries, so cheap control tools exist (e.g. vaccines for brucellosis, anthrax and rabies; anthelmintics for dogs and pigs). 2. NZDs can often be controlled in the animal reservoir at low cost (e.g. vaccination of ruminants for brucellosis and dogs for rabies) with added impact on the burden of disease in humans. 3. NZDs tend to cluster, making targeted, rather than widespread

campaigns possible and 4. NZDs tends to overlap, which means that more than one zoonosis can be targeted simultaneously in an area (WHO/DFID, 2006).

1.7 The ICONZ project: advancing knowledge into NDZs

ICONZ or the 'Integrated control of Neglected Zoonoses' is a collaborative research project funded by the EU under Framework Programme 7 (FP7) which endeavours to address some of the gaps in knowledge surrounding neglected zoonoses and their control in Africa. The focus on Africa recognised the benefits accruing from control of neglected zoonoses in developing countries would be higher in this region of the world, as 35 of the world's least developed countries are in Africa (Economic and Social Council of the UN, 2003); more than 30% of African countries have three or more recognised NZDs in various combinations. Countries selected for the field-based 'Case Studies' are Mali, Morocco, Mozambique, Nigeria, Tanzania, Uganda and Zambia. The zoonoses selected were grouped into four clusters, offering opportunities for synergy and added value of research and control interventions:

- Bacterial zoonoses (anthrax, brucellosis and bovine tuberculosis)
- Dog/small ruminant zoonoses (rabies, cystic echinococcosis and leishmaniasis)
- Pig associated diseases (*T. solium* cysticercosis/taeniosis)
- Vector-borne diseases (zoonotic trypanosomiasis, tick-borne animal diseases, malaria)

The Case Studies are central to the work of ICONZ and comprise three phases. The first phase involves the collection of data on the societal 'burden' or impact of a specific disease cluster on human and animal populations. The societal 'burden' estimate is derived from human and animal seroprevalence surveys, socioeconomic data on animal production losses, monetary expenditure on human and animal health and non-monetary losses to human health (DALYs). Participatory research methods are used at baseline to establish current knowledge, attitudes and practices with regards to presence, transmission factors, impact and control of zoonotic diseases under study. Phase two consists of designing, planning and piloting an intervention based on the evidence collected during Phase 1, taking into account economic,

epidemiological, sociological and cultural aspects of disease as well as traditional knowledge. Cost-effectiveness of the intervention is demonstrated in Phase 3 (to determine whether the intervention had a measurable impact within the timeframe of the project). This is accomplished by comparing the costs in terms of burden or losses of a disease cluster against the benefits and costs (modelled or real) of disease control, thereby demonstrating the added value of integrated intervention packages.

The work described here is a component of the ICONZ Nigeria Case Study, which focuses on the bacterial zoonoses cluster (brucellosis specifically) in human and animal populations in the Kachia Grazing Reserve (KGR) (see Chapter 3 Figure 11 for location). The KGR is rangeland set aside by the government to promote sedentarisation of Fulani pastoralists who own 90% of cattle in Nigeria.

1.8 Early study hypotheses and objectives

The original and overarching hypothesis of the study was the existence of a dual (human and animal) burden of bacterial zoonoses in poor-livestock keeping pastoralist communities of Nigeria, and the cost-effectiveness of control interventions. The elements required to test this hypothesis include quantification of the economic burden of disease in humans and animals at community level and the cost of rolling out a control intervention (Figure 1).

The initial strategy was to gather human and animal data on prevalence of brucellosis and bovine tuberculosis and on the cost of disease in parallel during a single survey incorporating biological sampling in humans and animals, questionnaire administration and participatory methods (focus group discussions and key informant interviews). Collecting inter-disciplinary data during a single survey in March 2011 proved to be a practical impossibility: the tuberculin testing reagents were not available until June 2011, and the ethical clearance for human screening was only obtained in September 2011. For this reason three separate surveys were undertaken.

The first survey took place in March 2011 and incorporated cattle and small ruminant screening for brucellosis. The KGR pastoralists were assumed to be sedentary and it was not until the fieldwork had commenced that it was realised this time of year coincided with dry season transhumance and that many households had taken part of

or their entire herd away from the KGR. For this reason and the fact that tuberculin testing had not been undertaken, the March survey was regarded as a 'pilot' and a second survey incorporating cattle brucellosis screening alongside TB testing was programmed for June 2011. Sampling of small ruminants was to be undertaken in parallel, but pastoralists rarely accepted due to the time consuming nature of the tuberculin testing in cattle. Hence a limited number of sheep and no goats were sampled. A census was undertaken prior to the June 2011 survey because of a mass immigration event into the KGR as a result of the post-election violence of April-May 2011 to provide a contemporaneous sample frame for this dynamic system.

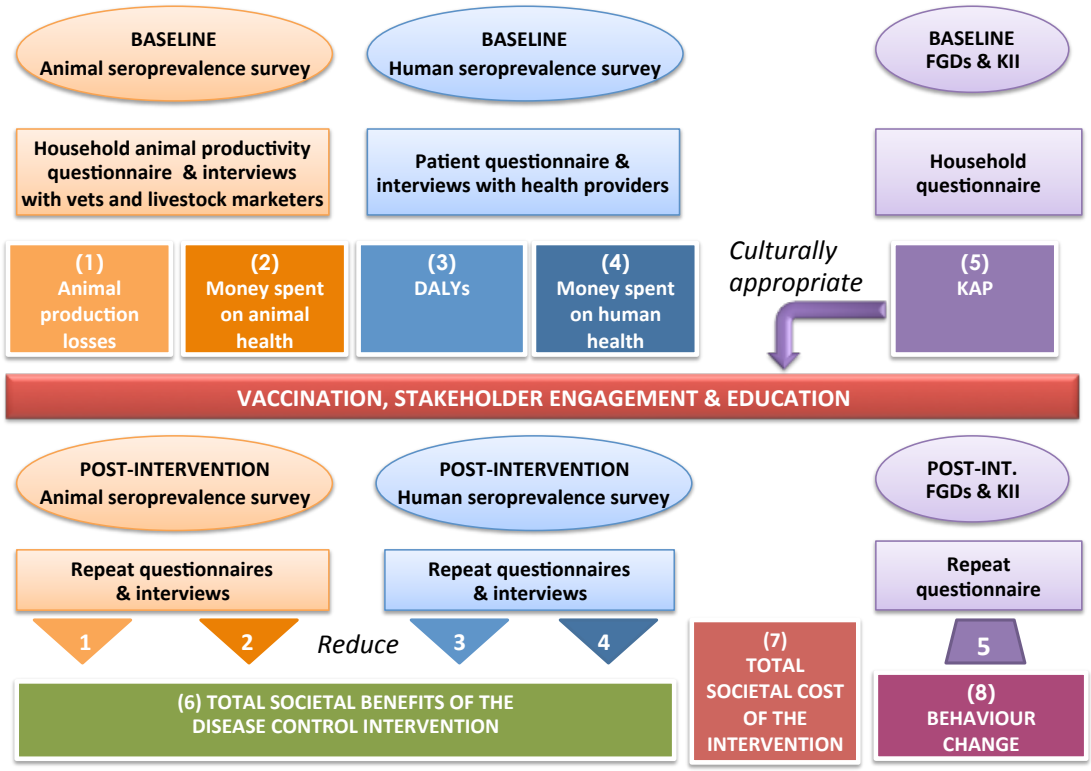


Figure 1 Original layout of study as per the ICONZ structure

Ethical approval for human sampling was obtained in September 2011, after which the third and final survey was undertaken. The strategy was to sample humans as well as small ruminants from randomly selected households as few small ruminants had been sampled during the two previous surveys.

The results of the three surveys were unexpected. Previous studies undertaken by Nigerian colleagues in KGR, had shown an individual brucellosis cattle prevalence of 8%. Very low seroprevalence of brucellosis and bovine TB was, however, detected in cattle, and no or few sheep, goats or human were found to be brucellosis seropositive. Without human brucellosis cases data could not be gathered on the cost of human disease, and with so few seropositive cattle the data lacked statistical power to test differences in productivity between seropositive and seronegative cows.

The initial plan was to conduct a separate brucellosis survey in Fulani pastoralist communities of the Jos Plateau, first of all to determine if brucellosis prevalence in this setting was as low as that found in the KGR, and secondly to gather data on the livestock productivity impact of disease. Plans were also made to undertake a hospital study at the large tertiary Jos University Teaching Hospital (JUTH) to screen human sera and trace human cases of brucellosis to capture costs of human disease. Unfortunately, due to mounting violence and political tension, the University of Edinburgh prohibited travel to Jos. It was for this reason that the objectives and layout of the thesis shifted, as the initial hypotheses could no longer be addressed.

The author of this thesis spent a total of 6 months in the KGR. Based on the intimate knowledge developed of the setting and its community, new themes were identified and the thesis workplan was altered to that illustrated in Figure 2.

Firstly, the KGR community had been assumed to be a sedentary populace and it was wrongly assumed that they did not practice transhumance. In addition, KGR was found to be highly heterogeneous and dynamic system, with influx of Fulani from surrounding areas during periods of conflict. Capturing these aspects was deemed important, firstly to dispel the misconceptions surrounding Fulani socioeconomic characteristics in grazing reserve settings and secondly, as a component of a system's approach to explain the patterns of disease and productivity observed.

A second emerging theme addressed the question: 'why is the prevalence of brucellosis so low in the presence of *Brucella'*. Most work presented in this thesis focuses on theme: critical appraisal of evidence of brucellosis in Nigeria; performance of diagnostic tests in KGR; epidemiological aspects of brucellosis in

KGR; community knowledge, attitudes of practices of relevance to brucellosis transmission in the KGR. Control options for Nigeria and KGR are explored.

A third theme explored the question: 'if brucellosis is not a priority for KGR, what other livestock and human diseases are important?'. For this component, epidemiological data collected in parallel to brucellosis screening during the three surveys was compared to data on community disease ranking and perception.

Finally, the fourth theme linked back to the original ICONZ hypothesis and consisted of critically evaluating the ICONZ model as a way to investigate community health and evaluate the integrated, disease cluster - 'One Health' approach.

The chapters addressing each theme are shown in Figure 2. The objectives emerging from the four themes are described below:

1) Socioeconomic profiling of the KGR (Chapters 3, 4 and 5)

- Analyse the drivers of pastoralist migration to grazing reserves including trends in livelihood change, political instability and conflict in Nigeria;
- Understand the social and economic dynamics of pastoral communities and their livelihood strategies to inform locally adapted approaches to disease control;
- Assess variation in KGR household characteristics (household size, composition and economy);
- Categorise households using proxies for wealth status to explore variation in sources of income and livelihood diversification;
- Explore livestock management, migratory habits, and livestock productivity, including herd composition and herd dynamics of households in KGR.

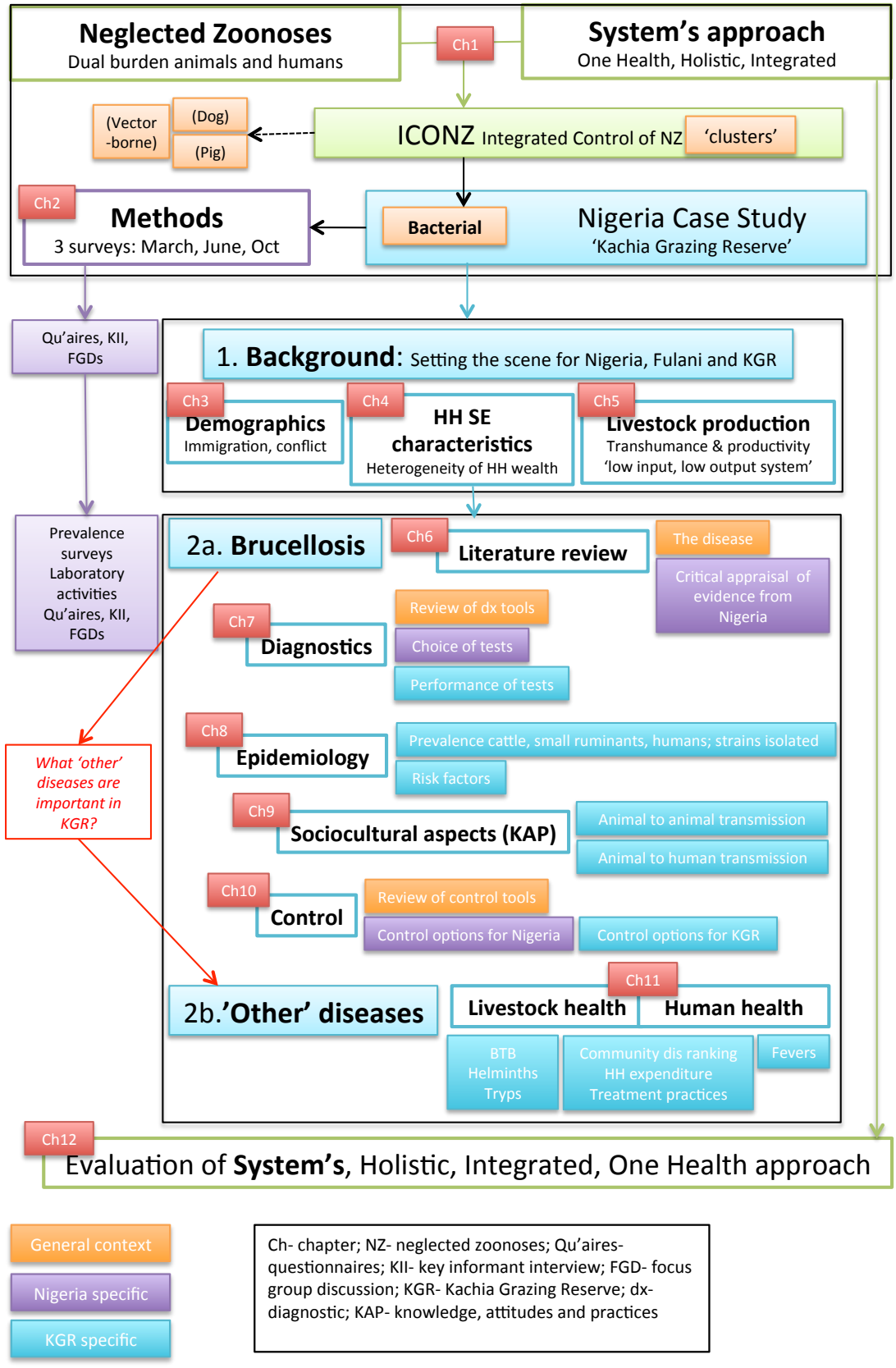


Figure 2 Schematic diagram of the different components of the study as presented in the thesis

2) Animal and human health in the KGR (Chapters 6, 7, 8, 9, and 10)

a) Brucellosis

- Review and appraise the evidence surrounding human and animal brucellosis burden in Nigeria across contrasting livestock production systems;
- Review and compare tests commonly used for the diagnosis of brucellosis;
- Assess simple tests under field and laboratory conditions in Nigeria;
- Assess the suitability and performance of tests selected for use in the KGR to inform recommendations about use of tests in a wider resource-poor context;
- Measure animal and human burden of brucellosis in KGR;
- Examine prevalence and risk factors for brucellosis in KGR;
- Compare burden across different species (animal and human) and determine *Brucella* species present in KGR to define the role of the different hosts both in disease transmission and as reservoirs of disease;
- Explore social factors, including knowledge, attitudes, behaviours and practices of KGR community members, which may promote or prevent brucellosis transmission;
- Make specific recommendations for brucellosis control in the KGR based on the findings of the KGR surveys and analysis of questionnaire data on community attitudes to brucellosis control;
- Assess prospects and recommendations for control of brucellosis in Nigeria.

b) Other diseases – i) Animal health (Chapter 11)

- Examine pastoralist knowledge and understanding of disease conditions and treatment and prophylaxis use in KGR;
- Compare findings on community perception of disease gathered through qualitative methods (participatory rural appraisal) with quantitative epidemiological data on disease prevalence for a range of ruminant disease;
- Determine household expenditure on animal health;
- Critically evaluate current community approaches to disease control and treatment and prevention practices in cattle and small ruminants;

- Make animal health recommendations for the KGR community and determine animal health priorities based on community ranking and epidemiological evidence.

ii) Other diseases- Human health and fevers

- Determine burden of fevers in KGR;
- Examine community perception, knowledge and understanding of conditions causing fevers;
- Examine health-seeking behaviour for fevers and household costs associated with treatment of fevers;
- Make recommendations on ways to improve community treatment and prophylaxis of fevers in KGR.

3) One-health approaches to disease control (Chapter 12)

- Evaluate the bacterial zoonosis cluster approach to disease control;
- Evaluate the multiple animal disease approach;
- Evaluate the parallel, multiple host approach;
- Evaluate the interdisciplinary (qualitative and quantitative) approach.

2 Chapter 2 Study Design

2.1 Study area

The study site was Kachia Grazing Reserve (KGR) in northern Nigeria (Table 2). KGR has a total area of approximately 32 km^2 and is located between latitudes 10°03'-10°13'N and longitudes 7°55'- 8°06'E. With an altitude 700-900 m above sea level, the main fluvial system is the Kaduna River. The reserve is located within the sub-humid zone of Nigeria, comprising a mixed farming-pastoralist area displaying Northern Guinea-Savannah Woodland vegetation. The reserve is subdivided into six administrative blocks that display slightly different demographic and ecological characteristics (see Chapter 3 and 4).

The inhabitants of the reserve are agro-pastoralist Fulani, which are partially settled as they have a homestead and produce subsistence crops while still performing seasonal transhumance to areas with more favourable conditions for grazing at certain times of the year (see Chapter 5).

Name and location	Kachia Grazing Reserve, Kaduna State, Nigeria Size 31, 000 ha (32 km^2)
Demography	6 Blocks (Administrative Units) Human population: 18,000 Number of households: 777 Ethnicity: Fulani pastoralists and agro-pastoralists
Relevant animal populations	Cattle: 42,000 Sheep: 10,000 Goats: 5,000
Epidemiology	Mixed cattle, sheep and goat extensive breeding Semi-nomadic pastoralism still practiced Previous brucellosis screening in the area revealed a prevalence of 8.6% (Bertu W., pers. comm.)
Geography, topology, climate	Tropical sub-humid climate Typical Guinea Savannah- Forested areas and shrubs with undergrowth grassland Annual rainfall: 1000-1200mm Wet season: April - October Dry season: November - March Temp: avr: 28°C, min: 19°C (Jan), max 39°C (April)

Table 2 Demographic, epidemiological and geographical characteristics of study site, the Kachia Grazing Reserve

The KGR was selected as a study site for the following reasons:

1) Pastoralist (Fulani) inhabitants exhibiting more sedentary behaviour, suitable for potential intervention;

2) Perception of Fulani of a 'bakale' (brucellosis) and 'samore' (trypanosomiasis) problem;

3) Preliminary surveys that suggested a brucellosis seroprevalence of 8.6% in cattle (Bertu, W., pers. comm.);

4) Broader socio-political interest in the sedentarisation of Fulani in grazing reserves.

2.2 Study timeline

This multidisciplinary study comprises research on multiple diseases in multiple hosts using different disciplines including epidemiology (classical and participatory) and socioeconomics. This makes the study design complex. The fieldwork for this study was undertaken during three periods: March, June and October 2011. Laboratory work was completed between 2011 and 2014 (Figure 3).

This study is divided into six components: 1) censuses; 2) prevalence surveys; 3) individual animal/human data collection; 4) structured questionnaire surveys 5) focus group discussions (FGD) and key informant interviews (KII) and 6) diagnostics (subdivided into field and lab diagnostics). Each component is described below.

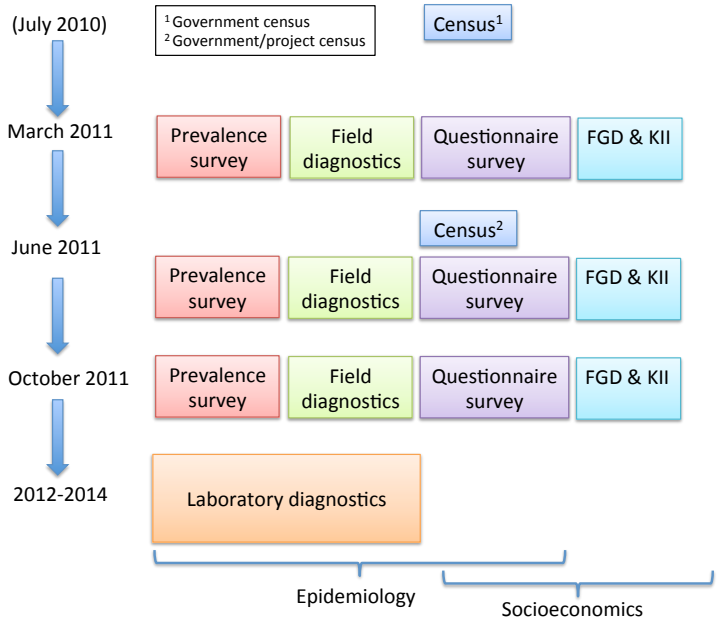


Figure 3 Study structure

2.2.1 Censuses

The KGR Project Office undertook a census in July 2010. All households were GPS geo-referenced (Garmin Geko™) and demographic details of the household members, year of settlement in the reserve and number and type of livestock kept were recorded. This census was used as the sampling frame for the March survey.

A second census was conducted in collaboration with the KGR Project Office in June 2011 and was selected as the sampling frame for the June and October surveys (Figure 4). For more information on census methodology refer to Chapter 3.

Figure 4 Project Officer interviewing a woman as part of census in June 2011

2.2.2 Prevalence surveys

While this thesis focuses on bacterial zoonoses (namely brucellosis) the ICONZ surveys were also designed to examine the prevalence of brucellosis, bovine tuberculosis (BTB), helminthiasis and trypanosomiasis in the KGR. Brucellosis was investigated in cattle, sheep, goats and humans. Trypanosomiasis surveys were undertaken in cattle, sheep and goats. BTB and helminthiasis were investigated in cattle only. While the focus of this thesis was to study the characteristics of brucellosis across different host species (Chapter 8), prevalence data for BTB, helminths and trypanosomiasis are also briefly discussed (Chapter 11).

The original strategy had been to undertake a single survey investigating multiple diseases in multiple hosts in parallel for efficiency. During the first field visit in March, however, it was not possible to undertake TB testing as reagents were not available nor had ethical approval for human brucellosis screening been granted. The

March survey also corresponded to a time when a large number of households had taken their cattle away on dry season transhumance. A second survey was scheduled for June, during which TB testing was completed and brucellosis screening in cattle was repeated as most households had brought their cattle back to the KGR at this time. A third and separate survey was programmed in October as soon as ethical clearance for human sampling had been obtained. The number of sheep and goats sampled during the March and June surveys had been low and it was decided to repeat small ruminant brucellosis screening during this survey.

Overall, three separate cross-sectional prevalence surveys were undertaken; the first was completed in March (mid-dry season), the second in June (beginning of wet season) and the third in October 2011 (end of wet season).

2.2.3 Original sample design March survey

The March survey was designed to estimate the prevalence of, i) *Trypanosoma vivax* and *Trypanosoma congolense* infection in cattle; ii) *Brucella* infection in cattle; and iii) *Brucella* infection in sheep and goats. A secondary goal was to estimate the prevalence of i) *Brucella* infection in humans; ii) *Mycobacterium bovis* infection in cattle; and iii) helminthiasis in cattle. The survey was designed with parameters specified for *T. vivax, T. congolense* in cattle. Samples sizes obtained were interpreted in the context of known parameters for *Brucella* spp. infections in goat, sheep and humans, BTB infections in cattle and helminthiasis in cattle.

2.2.3.1 Parameter specification for sample survey

2.2.3.1.1 Population sizes

Census data (KGR Administration census, July 2010) were used as the basic data frame to draw samples for the March survey. The Blocks contained a total of 581 farmers (heads of households) and 5,252 people. The number of households per Block ranged from 80 (Blocks 5 and 6, together) to 188 (Block 2). The median household size was eight (range of 1-44 people). 569 households owned cattle with 23,327 animals. The median number of cattle per cattle-owning household was 29 (range of 1-303). The Fulani concept of ownership is further explores in Chapter 4.

Four hundred and fifty two of 580 households (one missing value) owned sheep, of which there were 5,914 animals. The median number of sheep per sheep-owning household was 9 (range of 1-110). Three hundred and eighty six of 579 households (two missing values) owned 5,058 goats. The average number of goats per goat-owning household was nine, with a range of 1-100.

2.2.3.1.2 Trypanosomiasis parameters

- *Anticipated prevalence:* This was assumed to be 45%, based on a cluster-sample survey conducted in 2008 to determine the prevalence of bovine trypanosomiasis (*T. vivax* and *T. congolense*) on the *Jos Plateau*, which found an average prevalence in 30 villages of 46.3% (Majekodunmi et al., 2013).
- *Precision of the sample estimate***:** set at ± 5%.
- *Degree of confidence***:** set at 95%.
- *Definition of a cluster:* A cluster is defined as a household.
- *Rate of homogeneity:* A Rate of Homogeneity (ROH) of 0.18 was used, based on the results of the 2008 survey (Majekodunmi et al., 2013).

2.2.3.1.3 Brucellosis, BTB and helminthiasis parameters

The sample size was fixed by the trypanosomiasis survey parameters, and the adequacy of sample this size, in terms of precision (width of the prevalence estimates' confidence intervals), at specified levels of confidence, judged for each host. The parameters applied are shown below. The ROH was assumed to be 0.20 since it rarely exceeds this value (Otte and Gumm, 1997).

2.2.3.1.3.1 *Brucella* in cattle

- *Prevalence:* 8.6% (KGR pilot study, Bertu, W., pers. comm.)
- *Degree of confidence:* set at 95%.
- *ROH:* A value of 0.20 is used.

2.2.3.1.3.2 *Brucella* in sheep and goats

- *Prevalence:* Values of 9.3% and 10.1% were reported for sheep and goats respectively by a recent survey on the Jos plateau in Fulani and local flocks, private and government semi-intensive flocks (Bertu et al., 2010).

- *Degree of confidence:* set at 95%.
- *ROH:* A value of 0.20 is used.

2.2.3.1.3.3 *Brucella* in humans

- *Prevalence:* Values as high as 59% have been recorded in Nigeria (Alausa, 1977). A conservative value of 50% is used.
- *Degree of confidence:* This is set at 95%.
- *ROH:* A value of 0.20 is used.

2.2.3.1.3.4 BTB in cattle

- *Prevalence:* A value of 1.1 % was reported for a study in northern Nigeria (Ibrahim et al., 2010b).
- *Degree of confidence:* This is set at 95%.
- *ROH:* A value of 0.20 is used.

2.2.3.1.3.5 Helminthiasis in cattle

- *Prevalence:* A conservative value of 50% is used.
- *Degree of confidence:* This is set at 95%.
- *ROH:* A value of 0.20 is used

2.2.3.2 Sample size determination

A cluster sampling methodology (Bennett et al., 1991; Thrusfield, 2007), implemented in C Survey version 2.00 (Farid and Frerichs, 2007), was used. Assuming all cattle in each selected household are sampled, the number of animals per cluster is defined as the median number of cattle per cattle-owning household. The number of clusters required fulfils the sampling assumption that the cluster means are normally distributed.

- Number of clusters = 88
- Number of cattle per cluster = 29

2.2.3.3 Estimates of precision

Estimates of precision for brucellosis infection in sheep, goats and humans, BTB and helminths in cattle are summarised in (Table 3). For the sensitivity analysis it was

conservatively assumed that only 30% of clusters (26.4 conservatively rounded down to 26) would contain either sheep or goats.

Infection	*Precision, % (n clusters)*			
	Cattle	Sheep	Goat	Humans
Brucellosis	5.8-11.4 (88)	3.0-15.6 (26)	3.6-16.6 (26)	44.2-55.8 (88)
BTB	0.0-2.1 (88)			
Helminthiasis	44.2-55.8 (88)			

Table 3 Sensitivity analysis of estimated precision, at 95% level of confidence, of prevalence for brucellosis, BTB and helminthasis for different species using values from 2.2.3.1.3. and based on sample size fixed by trypanosomiasis survey parameters

2.2.3.4 Deviation from original protocol

Approximately 40% of households resident in the KGR had taken their entire herd on dry season transhumance outside the reserve in March 2011 so it was not possible to adhere to the original sampling protocol. A new list of households that had not left for migration was drawn up and households randomly selected from this. The strategy was to sample the same number of households per block as defined in the original protocol (18, 29, 14, 14 and 13 from blocks 1, 2, 3, 4 and 5&6 respectively). Due to problems with cooperation and many herds from blocks 4, 5 and 6 having left the KGR on transhumance, the original sampling targets were not reached. In the end 18, 28, 13, 4 and 1 households were sampled from blocks 1, 2, 3, 4 and 5 respectively. Poor household cooperation in blocks 4, 5 and 6, the most remote blocks furthest away from the market centre of the reserve, was due to poor sensitisation of community members in this part of the reserve as compared to those resident in the more central blocks 1, 2 and 3.

Overall, cattle were blood and faecal sampled from 64 households, sheep blood sampled from 26 households and goats blood sampled from 9 households (Table 5). All cattle over 6 months and all small ruminants except neonates from a selected household were sampled. No cattle were tuberculin tested because reagents and equipment were not available. A low number of households were sampled for goats because this species, as compared to sheep which are reared alongside the cattle herd, are free-range during the dry season and were therefore rarely at the homestead

during the team visit. Humans were not sampled because ethical clearance had not been obtained at this time. Ethical consent was obtained for animals.

2.2.4 Sample design June and October survey

Surveys undertaken in June and October were to estimate the prevalence of i) *Brucella* infection in humans; ii) *M. bovis* infection in cattle and iii) *Brucella* infection in sheep and goats. Secondary goals were estimated prevalence of i) *T. vivax and T. congolense* in cattle; ii) *Brucella* infection in cattle iii) helminthiasis in cattle and iv) *T. vivax and T. congolense* infection in sheep and goats.

Mass immigration into the KGR occurred in April-May 2011 due to post-election violence. The June 2011 census in KGR was used to update the sampling frame. Sample size was fixed using parameters for human brucellosis parameters that gave the highest number of clusters to be sampled. Sample sizes obtained were interpreted from known parameters for *Brucella* infections in cattle, sheep and goats, BTB in cattle, trypanosomiasis in cattle, sheep and goats and helminthiasis in cattle.

2.2.4.1 Parameter specification for sample survey

2.2.4.1.1 Population sizes

In June 2011 KGR was comprised 777 households and 9,118 people. In total 27 households declined to participate in the census and 16 would not disclose information about their livestock, leaving 734 households. The median household size was 10 people, with a range of 1-68 people. 728 households owned cattle, with a total of 41,234 animals. The median number of cattle per cattle-owning household was 35, with a range of 2-2000. A total of 492 households own sheep, with 10,161 animals. The median number of sheep per sheep-owning household is 6, with a range of 1-1000. A total of 431 households own goats, with 4,828 animals. The average number of goats per goat-owning household was 4, with a range of 1-150.

2.2.4.1.2 Human brucelllosis parameters

- *Anticipated prevalence:* Assumed at 21%, based on a study in occupationally exposed groups in Northern Nigeria (Alausa and Awoseyi, 1975)
- *Precision of the sample estimate***:** set at ± 5%.

- *Degree of confidence***:** set at 95%.
- *Definition of a cluster:* A cluster is defined as a household.
- *Rate of homogeneity:* A value of 0.20 was used.

2.2.4.1.3 Trypanosomiasis, brucellosis, BTB, and helminthiasis parameters

The sample size was fixed by the human brucellosis survey parameters, the adequacy of sample this size, in terms of precision (width of the prevalence estimates' confidence intervals), at specified levels of confidence, is judged for each disease and host. The parameters used are given below.

2.2.4.1.3.1 Trypanosomiasis in cattle

- *Anticipated prevalence:* This at 8%, based on the results of the March 2011 KGR survey (Santirso-Margaretto et al., 2014).
- *Precision of the sample estimate***:** set at ± 5%.
- *Degree of confidence***:** set at 95%.
- *Rate of homogeneity:* A rate of 0.18 is used, based on the results of the Jos 2008 survey (Majekodunmi et al., 2013).

2.2.4.1.3.2 Trypanosomiasis in sheep and goats

- *Anticipated prevalence:* Values of 20% and 13% (Enwezor et al., 2006).
- *Precision of the sample estimate***:** set at ± 5%.
- *Degree of confidence***:** set at 95%.
- *Rate of homogeneity:* A Rate of 0.18 was applied

2.2.4.1.3.3 *Brucella* in cattle

- *Prevalence:* A value of 0.6% is used based on the results of the March 2011 KGR survey (Ducrotoy et al., unpublished).
- *Degree of confidence:* set at 95%.
- *ROH:* A rate of 0.20 was applied.

2.2.4.1.3.4 *Brucella* in sheep and goats

- *Prevalence:* Values of 0.4% and 0.0% applied based on the results of the March 2011 KGR survey (Ducrotoy et al., unpublished).

- *Degree of confidence:* set at 95%.
- *ROH:* A value of 0.20 is used.

2.2.4.1.3.5 BTB in cattle

- *Prevalence:* A value of 1.1 % was reported for a study in northern Nigeria (Ibrahim et al., 2010b)
- *Degree of confidence:* set at 95%.
- *ROH:* A value of 0.20 is used.

2.2.4.1.3.6 Helminthiasis in cattle

- *Prevalence:* A conservative value of 50% is used.
- *Degree of confidence:* set at 95%.
- *ROH:* A value of 0.20 is used

2.2.4.2 Sample size determination (See 2.2.3.2).

- Number of clusters = 79
- Number of humans per cluster = 10

2.2.4.1 Estimates of precision

Estimates of precision for brucellosis and trypanosomiasis in cattle, sheep and goats and for BTB and helminthiasis in cattle are shown in (Table 4). It was conservatively assumed for sensitivity analysis that only 30% of clusters (24) would contain either sheep or goats.

Infection	*Precision, % (n clusters)*		
	Cattle	Sheep	Goat
Trypanosomiasis	5.3-10.7 (80)	10.5-29.5 (24)	4.2-21.8 (24)
Brucellosis	0.0-1.4 (80)	0.0-1.9 (24)	0.0-0.9 (24)
BTB	0.0-2.2 (80)		
Helminthiasis	44.7-55.3 (80)		

Table 4 Sensitivity analysis of estimated precision, at 95% level of confidence, of prevalence for trypanosomiais, brucellosis, BTB and helminthasis in different species using values from 2.2.4.1.3 and based on sample size fixed by trypanosomiasis survey parameters

2.2.4.2 Deviation from original sampling protocol

2.2.4.2.1 June 2011 survey

The target of 79 households had to be reduced to 40 households for the June survey. The original plan had been to sample 4 households per day for 20 days in order to undertake the BTB survey as well as brucellosis, helminth and trypanosomiasis survey in cattle). Tuberculin testing doubled the number of household visits per day as each household tested has to be re-visited three days later to read the test. This increased the number of daily household visits to 8. Travelling to 8 households per day was not possible because: i) sampling could only be undertaken between 6 and 10.30 a.m. as the Fulani take their cattle away for grazing after this time and will not return to the homestead until nightfall and ii) June falls in the wet season and roads were so poor that travel between households took from 30 minutes to 1.5 hours. It was not possible to double the time spent in the field for financial reasons.

The only alternative, other than to abandon TB testing, was to halve the households sampled to two per day, which over 20 days was equal to 40 households. 40 households were re-selected randomly from the sampling frame (June 2011 census).

Some of the 40 households could not be sampled as access necessitated crossing of a river by car was too dangerous in the wet season. A foot and mouth outbreak in Block 1 meant that a lot of households within this block had left with their animals to avoid infection and some households refused to participate in the study. These households were replaced with the next unselected household in the list. Ultimately, a total of 6, 14, 6, 9, 4 and 1 household(s) were sampled from Blocks 1, 2, 3, 4, 5 and 6 respectively. Cattle were sampled for BTB, brucellosis, trypanosomiasis and helminths from all 40 households. Due to time constraints only 12 households were sampled for sheep and none for goats. Humans were not sampled as approval from the ethical committee had not yet been obtained. It was decided to postpone the small ruminant and human brucellosis surveys until October.

2.2.4.2.2 October 2011 survey

It was calculated that 79, rounded up to 80 households should be sampled as per the original protocol (2.2.4.2 Sample size determination). The original 40 households

sampled during the animal survey were included in the human survey and an additional 40 households were randomly selected from the sampling frame, giving a total of 80 households in which to perform human sampling of all persons over the age of 6. The limitation of this approach is that there is an inherent reduced probability of selecting a household from the sampling frame during the second random selection of 40 households, as it comprises 40 households less than the first. This difference in sampling fractions is trivial and can be tolerated. The advantage of re-sampling the original 40 households sampled during June is that association between cattle and human infection at household level can be investigated for those 40 households. All sheep and/or goats from the 80 randomly selected households that owned them were also sampled. Eight randomly selected households refused to take part in the study and were replaced with the next household on the list. Five households agreed to human and animal sampling but on the day refused to allow human sampling. Due to time restrictions these households were not replaced and only sheep and/or goats were sampled from five such households. A total of 52, 52 and 75 households were sampled for the sheep, goat and human surveys respectively.

2.2.5 Number and location of sampled households

The number of individuals and households sampled for each species and disease is summarised in Table 5. The location of households sampled for the March and June/October surveys is presented in Figure 5 and Figure 6. Note that all households sampled in June were also sampled as part of the October survey.

	Brucellosis	*BTB*	*Helminths*	*Trypanosomiasis*	*N ind*	*N HH*
March 2011	Cattle		Cattle	Cattle	1724	64
	Sheep				275	26
	Goats				79	9
June 2011	Cattle	Cattle	Cattle	Cattle	1982	40
	Sheep				121	12
October 2011	Humans				1126	75
	Sheep			Sheep	718	51
	Goats			Goats	779	51

Table 5 Species sampled for each disease and corresponding sample size (number of individuals and households) for March, June and October surveys

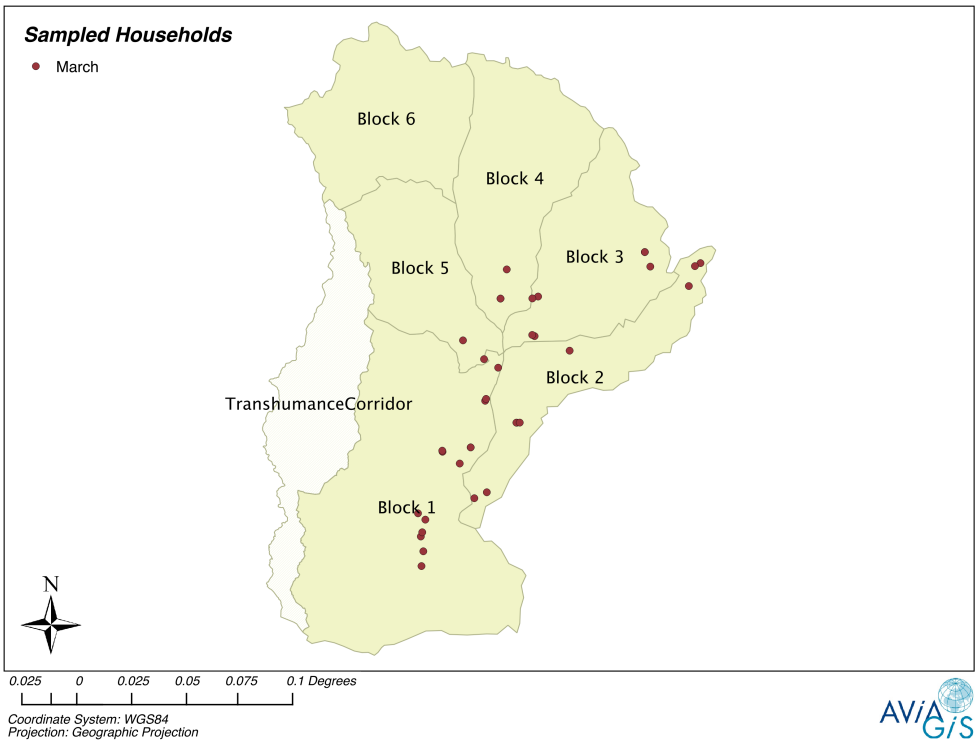


Figure 5 Households sampled during March survey

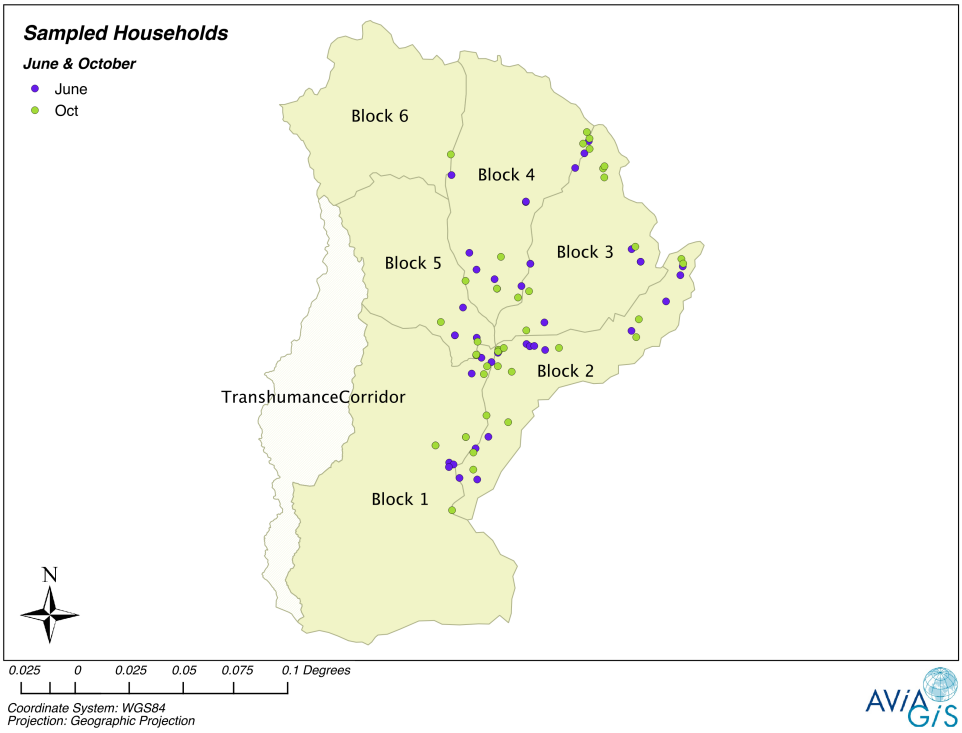


Figure 6 Households sampled during June and October surveys

2.2.6 Individual animal/human data collection

2.2.6.1 Cattle data

A '**Cattle Information Table**' (see appendix) was completed for each household selected for sampling during March and June surveys. The form recorded:

'Animal Number': a unique identifier given chronologically to all animals sequentially sampled to relate sex, age and parity of the animal to diagnostic data.

'Age': to determine the herd composition.

'Sex': to determine herd composition.

'Lifestage': e.g. calf, cow, heifer, bull, castrated male, draught animal.

'Total parity to date': for fertility parameters (divided into male and female).

The reason to distinguish between male and female calves is that these animals have different economic value. The term parity is not strictly correct here as the data gathered was number of live male and female offspring to which cows had given birth (i.e. a cow could have had one 'parity' or birth-giving episode but have given birth to 2 calves). This was explained to the individuals collecting data.

2.2.6.1.1 Numbering system

The identification of cattle was necessary for tuberculin testing (see appendix for protocol), as animals had to be successfully re-identified on Day 3 to observe skin reactions. This was accomplished by giving each animal in a household a chronologically assigned number: the number was painted on the animal's head and rump (to maximise the chances of at least one number being legible after 72 hours in rainy conditions). The name of each animal and its colour or other distinguishing features was recorded as an additional precaution. This method was found to be very effective and only twelve animals out of 1982 (0.6%) overall could not be re-identified on Day 3 (Figure 7, Figure 8 and Figure 9).

Figure 7 Numbering of cattle on rump: orange paint was visible on both white and black animals

Figure 8 Painted numbers on the head and rump of cattle for easier identification

Figure 9 Painting numbers on the rump of cattle

2.2.6.2 Sheep and goat data

The sheep and goat data recorded included, age, sex, and for sexually mature females, the number of male and female offspring to which they had given birth.

2.2.6.3 Human data

Individual human data was gathered from each person sampled. Each blood sample taken was chronologically assigned a number, and this same number was recorded on the human sampling recording form in order to correlate RBT data to other data. The data collected included: 1) blood sample number; 2) name, age, gender and occupation of person; 3) history of exposure: i) drinking of raw dairy product[1]; ii) preparing of milk products; iii) assisting with animal births; iv) slaughtering of animals; 4) presence of recurrent fevers that do not respond to malaria treatment.

Ethical approval was obtained from the Ministry of Health for the work (see appendix). Human subjects were recruited by firstly asking the household head if he consented to his household being selected for human sampling, and then oral consent was obtained from individuals over 6 years old within the household.

2.2.7 Questionnaire surveys and HH level data collection

2.2.7.1 HH level recording form

A ‘household identification and sampling information’ form (see appendix) was filled in for every household visited during each survey. The 'household identification' component of the form (which includes date, GPS references, name of household head, block number, village name etc.) enabled linking of individual animal/human data to questionnaire data for each household. Duplication of data collection on this form and the questionnaire enabled cross-referencing and quality assurance. 'Household sampling information' was important if all animals in the herd could not be sampled. The reason for inability to sample the whole herd as well as the age, sex and life-stage of animals not sampled were recorded.

[1] Raw milk products included raw milk or any other dairy product which was not boiled z as part of processing (e,g, yogurt and cheese)

2.2.7.2 Household questionnaires

A questionnaire (different for each survey) was applied to each household sampled during the March, June and October surveys. For the 40 households sampled in June and October, questions relating to HH characteristics and animal health were covered only during the June survey and questions relating to human health, only during the October survey (animal health questions were not duplicated, see Table 6). Topics and chapters presenting the data are shown in Table 6. Questionnaires are included in the appendix. The March, June and October questionnaires were undertaken with the assistance of a translator. Questionnaire respondents were the household heads (HHH) or sons/brothers of the HHH in a minority of cases (see Chapter 4).

Topic	*Survey*			*Chapter*
	March	June	October	
HH characteristics	Y	Y	Y (new HHs only)	4
HH income	Y	Y	Y (new HHs only)	4
Crop farming	Y	N	N	4
Livestock ownership	Y	Y	Y (new HHs only)	4&5
Migration	Y	Y	Y (new HHs only)	5
Cattle productivity	Y	Y	N	5
Livestock health	Y	Y	N	11
Cattle health costs	Y	Y	N	11
Animal brucellosis	Y	Y	Y (new HHs only)	8&9
Human brucellosis	N	N	Y	8&9
Human health problems and fevers	N	N	Y	11
Milk consumption and processing	Y	Y	Y	9
Attitudes to disease control	N	N	Y	10

Table 6 Questionnaire topics covered during March, June and October surveys and chapters where data presented

2.2.8 FGDs and KIIs

Participatory Epidemiology (PE) and Participatory Rural Appraisal (PRA) techniques (Catley, 2006, Catley et al., 2012, Chambers, 1994) were employed in this study. Data from these discussions/interviews is presented in different chapters (Table 7). Question guides for some of the FGDs/KII are included in the appendix.

Focus group discussions were undertaken with 6 to 12 same-sex persons (although on occasion more people turned up) (Figure 10). The author asked the questions, which were translated into Hausa or Fufulde (Fulani understand and speak both) by an interpreter, who then translated answers back into English. 'On-the-spot'

translation meant that discussions were not recorded for future translation. Discussions on specific topics were repeated until saturation was reached. As often as possible, topics were discussed with groups of men and groups of women. Key informant interviews (KII) were undertaken directly in English if the person's education status permitted it or with the assistance of a translator if not.

Figure 10 FGD with women (top) and butchers (bottom)

Topic	*Target*	*Chapter*
Focus group discussions		
Community wealth ranking	Men and women	5
Sale of dairy products	Members of women's cooperative	4&9
Consumption and processing of milk (from cow to mouth)	Women (housewives)	4&9
	Men (pastoralists)	
Sale and purchase of animals	Traders	5&9
Market chain networks	Traders	9
Human immigration patterns into KGR over time	Pastoralists	3
Herd management calendar and migration	Young pastoralists	5
Herding and cropping calendar and migration	Young pastoralists	5
Herding and cropping calendar and role of women	Old men	5
Role of women in HH income	Members of women's cooperative	5
Hanta (fluke)	Men (pastoralists)	11
Approaches to animal disease control	Men (pastoralists)	10&11
Post mortem evidence of animal diseases	Butchers	11
Ante mortem evidence of animal diseases	Traders	11
Human health seeking behaviour	Men	11
	Women	11
Key informant interviews		
Household composition	Women	4
Crop farming, KGR past and future	Elderly, educated, elite male; advisor to district head	3,4,5&12
Migration and livestock ownership, KGR past and future	Young pastoralist	3&5
Sale, purchase and loaning of bulls	Dairy cooperative president	9
Animal drug availability and prices	Drug shop owner	11
Animal health problems and approach to control	Project Officer of KGR	11
Role of the Project Office of the KGR	Project Officer of KGR	3
Experience of brucellosis, BTB, Hanta	Project Officer of KGR	9&11
	Area Veterinary Officer	9&11
Experience of human health problems, brucellosis and fevers	KGR medical doctor, private clinic	11
	Community health technician, NGO clinic	11
Prospects for pastoralism, cattle transhumance stock routes, grazing reserves	National Livestock Projects Department Staff	12

Table 7 FGD and KII topics, target groups/individuals and chapter in which data is presented

2.2.9 Diagnostics

Brucellosis, BTB and helminthiasis diagnosis was undertaken in the field using the standard Rose Bengal Test (sRBT), single intradermal cervical comparative test (SICCT) and MacMaster/ sedimentation and microscopy respectively (Table 8).

Brucellosis serology and bacteriology procedures are discussed in more detail in Chapter 7 and in the appendix. Diagnostic protocols are included in the appendix for all diseases except trypanosomiasis, which is a minor component of this thesis.

Disease	*Species*	*Sample*	*Field diagnostic*	*Lab diagnostic*
Brucellosis	Cattle	Serum, milk, vaginal swab, joint fluid (hygromas)	sRBT	sRBT, bacteriology, PCR
	Sheep and goats	Serum	sRBT	sRBT, mRBT
	Humans	Serum	sRBT	sRBT, SAT, Coombs, Brucellacapt®
BTB	Cattle	NA	SICCT	ND
Helminths	Cattle	Faeces	MacMaster/ sedimentation	ND
Trypanosomiasis	Cattle	Blood on FTA	ND	PCR
	Sheep and goats	Blood on FTA	ND	PCR

Table 8 Species targeted, samples collected and field and laboratory diagnostics used for investigation of brucellosis, BTB, helminths and trypanosomiasis

The June survey included tuberculin testing for BTB screening. During the first visit to a selected household, all cattle were blood sampled (5-10 ml of blood was collected from the jugular vein), faecal sampled and Day 1 TB testing procedures were completed (shaving, measuring of skin and injection of avian and bovine tuberculin). A vaginal swab was collected from females that had aborted in the last few weeks for brucellosis culture and isolation.

During the second visit to the same household (72 hours after the first visit), the day 3 TB testing procedures were undertaken (measuring of skin reactions). Milk samples were collected from all cattle that tested positive to the Rose Bengal Test (which had been run in the 72 hours elapsed since the first household visit). Vaginal swabs were collected from animals aborting since the first household visit.

2.2.10 Data processing

2.2.10.1 Data collection and structure

Data was obtained from various sources, including blood samples (cattle, sheep, goats and humans); faecal samples (cattle), vaginal swabs (cattle, sheep and goats), milk samples (cattle), questionnaires, etc. The data captured included: i) Information

on age, sex, life stage, number of calves, lambs or kids, body condition score (for animals) and on age, gender, occupation, history of exposure (for humans); ii) TB test results for cattle; iii) Laboratory results: coprology (egg counts for McMasters and parasite species for sedimentation, this was obtained for cattle samples only); RBT results (outcome was recorded as positive or negative); iv) Questionnaire data (both for human and animal survey) and iv) FGD and KII data.

Because of the different nature of all these records, they could not be recorded in a single table (as this would lead to duplicated data and empty cells). It was decided, that all data should be recorded into a database rather than a spreadsheet. Other advantages for using a database are that it is easy to: i) modify, add and delete entries; ii) design forms to enter questionnaire data; iii) query results and extract data of interest; iv) distribute the data (as all information is contained in one file).

2.2.10.2 Data entry

For 1, 2 and 3 above, digitizing data used Microsoft Excel as its duplication features and text manipulation formulae greatly reduced time for entering data. For 4 (see above), questionnaire results were entered into a tailor made Access form so that data entries are standardized avoiding typographical errors making use of drop-down menus, checkboxes, input masks, etc.

2.2.10.3 Data processing

Raw data were processed before import into the Access database because the original format of some of the fields was not suitable for data analysis. As adding animals from households living in different blocks of the grazing reserve resulted in recurring animal and household numbers, a unique ID had to be introduced. The ID consisted of seven numerical characters where the first represents the block number, the following three represent the household number within the block, and the last three represent the animal number within the household. For example, 1002018 is Block 1, household 2, animal 18. Records for cattle, sheep and goat were stored in different tables so the same ID system could be used for all species.

The age of young animals was often expressed as years and months. To get a more uniform way of expressing age; years and months were converted into a decimal

number of years. Therefore one should define categories when including age in a query (e.g. age>=1 and age <2).

Because life stage was not specified for every animal, missing values were reconstructed using age and sex information from other fields.

2.2.10.4 Data distribution

Data was distributed in a Microsoft Access database format. For this purpose, spreadsheet tables were imported and linked through a set of relaters. This enabled querying results of the different fieldwork activities including microscopy findings, Rose Bengal test results, georeferences and animal properties which were administered during sampling activities.

2.2.10.5 Data analysis

Data analysis is discussed within each relevant chapter.

3 Chapter 3 KGR Demographics

3.1 Introduction

3.1.1 The Federal Republic of Nigeria

The Federal Republic of Nigeria comprises a large landmass of 923 768 km^2 located between 4°1' and 13°9' north and 2°2" and 14°30 east. Nigeria is bordered by the Republic of Niger and Chad in the north, Cameroon in the east, the Benin Republic in the west and the Atlantic Ocean in the south (Aregheore, 2009). Governance in Nigeria has transitioned from an amalgamated British colony in 1914, to an independent Federal Republic in 1963 (independence was granted in 1960). Abuja replaced Lagos as the official federal capital city in 1991. The current administrative division that emerged in 1996 comprises 36 States and 744 Local Government Areas.

Kachia Grazing Reserve (KGR), known as Ladduga by its Fulani inhabitants, is located in Kaduna State. KGR lies between the urban centres of Kaduna and Zaria to the northwest, Jos to the southeast and Abuja to the southwest (Figure 11).

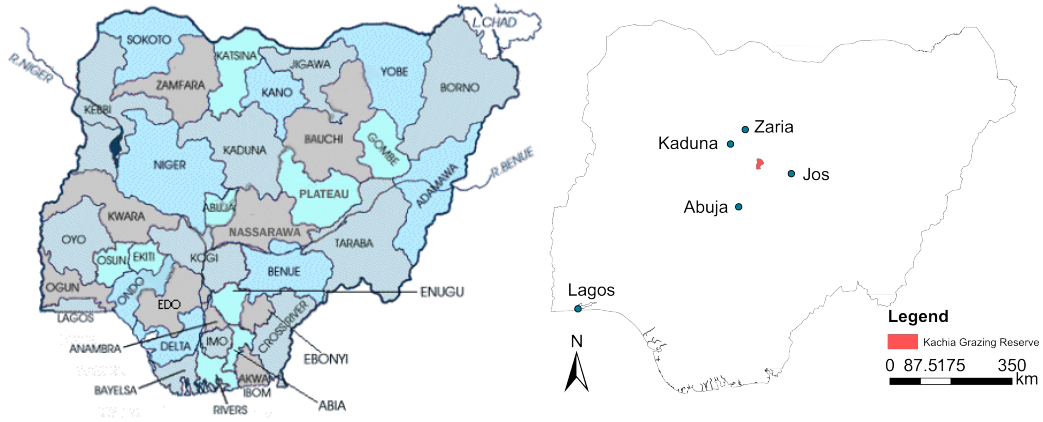


Figure 11 The 36 states of Nigeria (left) and location of the KGR (right) (map Ward Bryssinckx) (NgEX, 2014)

3.1.1.1 Population and land use

Nigeria, the most populous country in Africa reported a population of over 170 million in 2012 (UN, 2012), and is home to 478 ethnic groups. Hausa, Fulani, Yoruba, Igbo, Kanuri, Tiv, Edo, Nupe, Ibibio and Ijaw account for 80% of the population. The most populous and politically influential are Hausa and Fulani 29%, Yoruba 21%, Igbo 18%, Ijaw 10%, Kanuri 4%, Ibibio 3.5%, Tiv 2.5% (CIA, 2014).

Most people (53%) live in the North (79% overall land area), 25% inhabit the Southwest (12% of area) and 21 % in the East (9% of area) (Aregheore, 2009). Land use comprises 35-36% arable, 15-44% pasture, 10-12% forest reserves, 10% for settlements and 8-30% 'other' (Cleaver and Schreiber, 1994, FMEN, 2001). In 2012, 42.43% of Nigeria was estimated to be cultivated (FAO, 2013).

3.1.1.2 Economy and role of agriculture

Nigeria has the highest gross domestic product (GDP) ($292 billion) in sub-Saharan Africa ranking 31st worldwide (CIA, 2014). Oil was discovered in 1956 and Nigeria has the largest known reserves of petroleum and gas in Africa. Petroleum accounts for 85% of government budgetary revenues and over 90% of exports (Gboyega et al., 2011).

Dictatorship in the 1960s and 1970s resulted in poor governance and revenue management. The return of democratic rule in 1999 improved governance, but 70% of Nigeria's population live below the poverty line (CIA, 2014) and 35% live in conditions of extreme poverty (NPC, 2007). GDP per capita remains below US$1,200 (Gboyega et al., 2011). Nigeria has a Human Development Index of 0.47 with the number of undernourished people accounting for 6.26% of the overall population (10 million people) (FAO, 2013). An assessment of household income categorised poverty in KGR as 'very poor' (Figure 12).

Prior to independence and the oil boom, agriculture accounted for > 50% of GDP and > 75% of export earnings. With rapid oil industry growth, agricultural development experienced a decline. The shift away from self-sufficiency, high population growth, migration to the cities has led to high dependence on imports, an increased demand for meat, and the rise of subsistence oriented agriculture. Agriculture, industry and

the services sectors contribute 43%, 31% and 26% respectively to national GDP with labour force by occupation being 70%, 20% and 10% for those sectors (CIA, 2014). Agricultural GDP comprises 85% crops, 10% livestock; 4% fisheries 1% forestry. Agriculture provids employment for over 90% of rural inhabitants or 70% of the population (Akinyele, 2009).

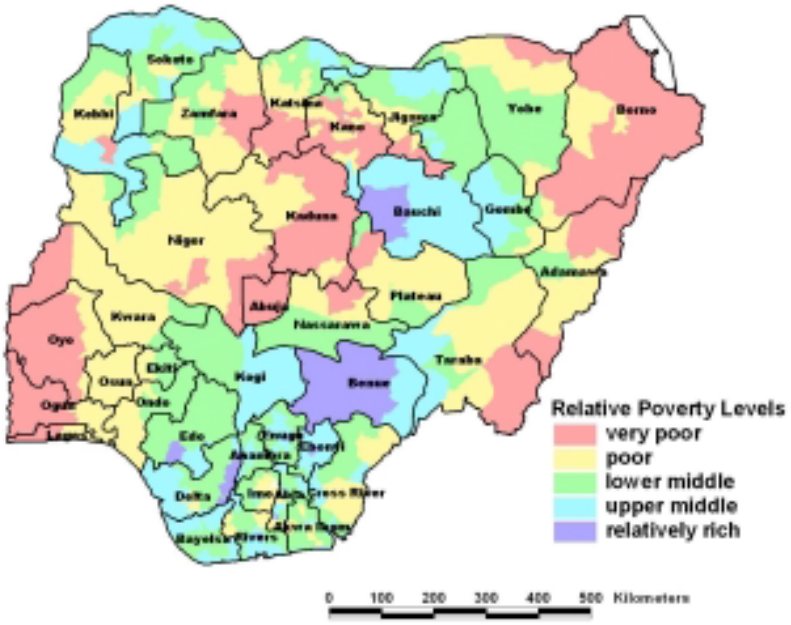


Figure 12 Map of relative poverty levels based on household income, International Institute of Agriculture (Legg et al., 2004)

With a large pastoralist population, the livestock industry has been a major focus of government attention (Box 1). Increased demand for animal products from a rapidly expanding population has resulted in expansion of livestock trade, animal and human movements and intensification of livestock production systems.

Box 1. SIGNIFICANT EVENTS FOR LIVESTOCK MANAGEMENT AND GOVERNMENT POLICY IN NIGERIA

Pre-colonial era (before 1900)

- Livestock production (cattle and small ruminants) dominated by nomadic pastoralism (Fulani) in the savannah region of northern Nigeria. Agricultural land open to grazing post-harvest with mutual benefit of Fulani and settled farmers (fertilising effect of cow dung).
- Fulani pastoralists paid cattle tax "jangali" to local rulers (continued under British indirect rule).

British Colonial Administration

- **1900-1930.** Tsetse eradication, livestock breeding programmes and mixed farming approaches. Establishment of Government Veterinary Field and Research Centres (Zaria, 1913; headquarters moved to Vom in 1924; expanded to include vaccine production).
- **1930s.** Government sets up stock farms to improve local breeds (White Fulani, Gudali and Shuwa). 'Mixed Farming Policy' (use of grasslands and pasture by introducing fodder and selected browse plants) to promote agro-pastoralism and range management and livestock productivity.
- **1940s.** Establishment of dairy herds and milk processing plants in Vom and Agege to meet expatriate population demand in Jos and Lagos.

Independence (1951) to Civil War (1967-1970)

- **1950s.**

– Livestock Improvement and Breeding Centres established in Southwest to improve indigenous cattle (taurine West African Shorthorn breeds the Muturu and Keteku) by crossing with N'dama breed (from Guinea, Sierra Leone and Congo). N'dama becomes the breed of choice in Southwest (white Fulani remain dominant in the North).

– Western Nigerian Development Corporation established to promote importation of non-autochthonous breeds (South Devon cattle, Friesians, Holsteins, Brown Swiss, Jerseys) to upgrade local stock and increase milk production (most multiplication centres established in the Southwest, with some in the East and North).

– Programmes to encourage settlement of nomadic pastoralists launched (supplementary feeding programme to secure year-round fodder [1962]; grazing reserves [1965 onwards] to protect grazing lands from expanding crop-farms and to resolve clashes over land use). This policy also reflected a desire by the state for pastoralists to be settled, more easily taxed and controlled.

- **1960s**.

– Smallholder steer fattening scheme (FAO project) using semi-intensive management systems introduced in the Southwest to ensure supply to local slaughterhouses.

– Grazing reserves established covering a total of 2.3 million ha by 1980 (Oxby, 1982)

– Cattle fattening ranches were established at Mokwa and Manchok.

Post-Civil war to present

- **Early 1970's.** Nigerian Livestock and Meat Authority established to regulate all aspects of livestock industry and trade. Heavy investments in intensive feedlot fattening for beef.
- **1976** Jangali abolished
- **1980s** Investment in direct livestock production reduces as the government focuses on livestock trade policy and oil industry. Dairy plants established in Minna, Vom, Kaduna but inadequate prices cause many to close down.
- **Post-1996** Government Structural Adjustment Programme Role (GSAPR) in livestock production initiated in 1986 to reform the Nigerian economy, including the livestock sector. The program dwindles, leading to a dominance of the private sector in livestock production. Research institutes (set up in the 1940s) no longer given any priority for funding.

3.1.1.3 Climate and agro-ecological zones

The climate in Nigeria ranges from semi-arid and desert-like in the north to tropical and wet in the south. Aridity and temperature increase northwards (Azuwike and Enwerem, 2010). The south of Nigeria experiences four seasons: a long wet season from mid-March to July, a short dry season from July to August, a short wet season from August to October and a long dry season from October to March. The North experiences a long wet season commencing in April and finishing in October and a long dry season from October to April (Aregheore, 2009). In the far north the dry season will come earlier and will last longer than in the southern zones, where the wet season is prolonged and dry season shorter.

The agro-ecological zones of Nigeria have been extensively classified (Oyenuga, 1967, Iloeje, 2001). The south transitions from very humid, to sub-humid in the middle-belt, to semi-arid in the north (Figure 13). The KGR is in the sub-humid zone. Agriculture in southern Nigeria is focused on timber, tree crops and root crops, the middle belt on root crops and cereal, and the northernmost parts on cereals and livestock, particularly cattle (Azuwike and Enwerem, 2010).

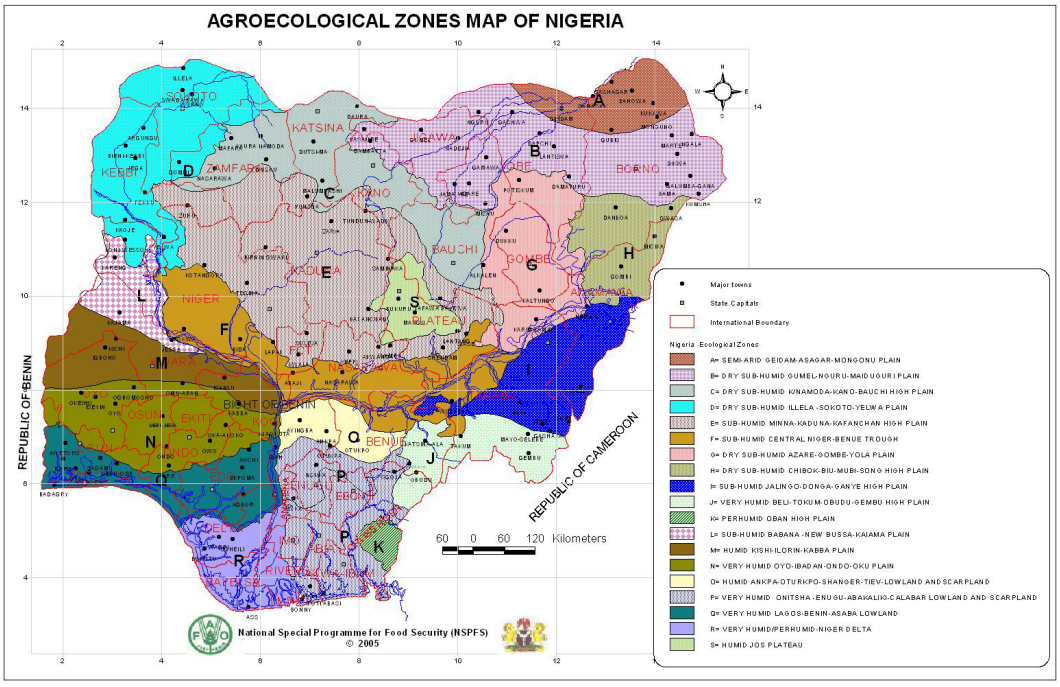


Figure 13 Agroecological zones of Nigeria (FAO, 2005)

The vegetation zones of Nigeria from north to south include: 1) Sahel (dry zone - camels and goats) 2) Sudan savannah (lighter woodland); 3) Guinea savannah (a heavier type of woodland); 4) tropical rain forest or Guinea forest (thick climax vegetation) and 5) mangrove swamp (Akinyele, 2009, Stenning, 1957).

Livestock were traditionally concentrated in the savannah zone as the Guinea forest was densely forested and the Sahel too dry (Stenning, 1957). Through the practice of transhumance, pastoralists were able to exploit the impact of seasonal changes on tsetse distribution and availability of pasturage in both the Sudan and Guinea savannah (semi-arid and subhumid zones). In the peak of the wet season, pastoralists concentrated in the northern tsetse-free zone of the Sudan savannah territory to avoid trypanosomiasis risk in the southern Guinea savannah. The dry season starts earlier in the north of the savannah zone and as it extended slowly southwards it caused the tsetse to retreat. With the onset of the Harmattan (dry season), herds in the north moved south in search of pasture without risking trypanosomiasis due to the reduced fly density (Stenning, 1957).

Transhumance is practiced to accommodate variations in available vegetation and agricultural practices and to avoid tsetse flies (Majekodunmi et al., 2013). This pattern of transhumance, although widespread, is now under threat from land use pressure, land rights issues, governmental policies and impacts from environmental change. Deforestation of the Guinea savannah and rainforest have pulled cattle into these zones year-round (Azuwike and Enwerem, 2010) and desertification of land in the north due has pushed pastoralists further south (HPG, 2009). Changes in land use and the resulting conflicts between Fulani pastoralists and indigene crop farmers has discouraged transhumance and encouraged sedentarisation. The ‘gradual displacement of customary transhumance tracks and orbits’ has been defined as ‘migratory drift’ (Stenning, 1957).

3.1.1.4 Livestock production systems

Nigeria has an estimated livestock population of 20.49 million cattle, 23.07 million sheep, 28.07 million goats, 6.54 million pigs (FAO, 2014b), 18,200-90,000 camels and 210,000 horses (FAO, 2014a, Adamu and Ajogi, 1999). Geographic, economic

and social conditions across Nigeria determine the ruminant livestock production systems (Aregheore, 2009) (Box 2). Small ruminants, in nomadic systems serve as a 'current account' and are sold and exchanged, whereas cattle are traded for status and serve as a 'savings account' (Alausa, 1979c, Brisibe et al., 1996).

Most cattle (80%) are *Bos indicus* and are concentrated in the north (savannah zone), with only 10% of the remaining 20% (mostly *Bos taurus*) in the south (Aregheore, 2009). Cattle are extensively managed under nomadic or semi-nomadic pastoral systems or, to a lesser extent under traditional village systems (in contact with small ruminants of the same household). There is significant contact between cattle and sheep that are co-grazed (goats are left to scavenge free-range).

The Fulani have dominated cattle production in this part of Africa for centuries (Azuwike and Enwerem, 2010). The Fulani manage 90% of Nigeria's ruminants and traditionally practice seasonal transhumance or year-round nomadism (Suleiman, 1988, Rikin, 1988). Cattle reared in extensive systems of the north and northeast are transported across Nigeria to the abattoirs of the southwest to meet the high demand for meat from the economically developed south (Bale et al., 2003a, Alausa and Awoseyi, 1975). 20% of cattle are imported, mostly from Chad and Niger (Esuruoso, 1974a). In the humid areas of the southern, western, and eastern states, mixed crop-livestock systems dominate and sheep, goats and pigs are increasingly important.

Dairy production is concentrated in the north and the beef industry mostly in the south. There are few commercial and intensive farms and these are located on the periphery of major towns in northern and western Nigeria.

Pastoralism has been evolving in Nigeria with farmers often combining cattle production with crop cultivation (Iyayi et al., 2003). Herd sizes are decreasing as the pastoralists become more settled. A large population of agro-pastoralists settling in the hinterlands of the urban centres in Oyo State were cattle pastoralists displaced from their traditional territories in the North by a variety of agro-ecological and socio-economic factors (Mohammed, 1990). This influx has stimulated a more intensive, sedentary and market-oriented style of livestock management, in areas traditionally frequented by migratory Fulani during the dry season.

Box 2. Characteristics of ruminant livestock production systems in Nigeria adapted from (Aregheore, 2009)	
EXTENSIVE (SUBSISTENCE)	
North – Pastoral systems (Nomadic or semi-nomadic)	
Exclusive pastoralist	• Livestock only (range, crop residues) • Large herds • Year round movements, large range, no permanent homestead
Transhumant	• Livestock more than crop (range) • Large herds • Seasonal migration (quality of grazing and tsetse flies) • Permanent homestead
Agro-pastoralists	• Livestock more than crop (grazing near environs) • Medium size herds • Semi-settled, low range cattle movements
South & North – Traditional or village system (Sedentary)	
Seasonal tethering	• Crop more than livestock (cut-and-carry) • Small herds
Fattening	• Crop more than livestock (stall feeding) • Small herds
Scavenging	• Crop more than livestock (scavenging of food scraps in village) • Small herds
Compound dairying	• Crop more than livestock (stall-feeding or grazing close to homestead) • Small herds
Animal traction	• Cotton belt and elsewhere • 2-4 work oxen kept in compound
INTENSIVE AND SEMI-INTENSIVE (COMMERCIAL)	
All areas	
Mixed farming	• Crop income equals or exceeds that from livestock (integrated cropping with livestock rearing) and use of animal traction • Variable size
South & North	
Peri-urban & modern husbandry	• Livestock only (crop residues, agricultural by-products, grazing) • Variable size

3.1.1.1 The sub-humid zone

This sub-humid zone (40% of Nigeria's total land area) lies in the Middle Belt. The zone is sparsely populated containing only a quarter of the Nigerian population. Low population density has been attributed to poor soil fertility and high tsetse and trypanosomiasis challenge. The zone is an example of *Grenzwildnis* (Ford, 1971) – a boundary wilderness, an under-populated no-man's land that separated the city-states of northern Nigeria from the southern coastal kingdoms. It forms part of a belt that stretches across West Africa from Cameroon to Senegal, and is associated with high tsetse challenge. Land-use pressures and conflict in other zones have resulted in increased migration into this previously sparsely inhabited zone. Expansion of cultivation has reduced suitable tsetse habitat, making the area more hospitable to livestock keepers (Waters-Bayer and Taylor-Powell, 1984a).

Prior to the 1950s, Fulani herds from the north traditionally grazed in the sub-humid zone only during the dry season, when the tsetse and trypanosomiasis pressures were low. There has been a gradual shift southwards into this zone for year round grazing and Fulani now comprise about 5% of the rural population of this zone (the majority of whom have embraced agro-pastoralism and abandoned their nomadic traditions). In the 1980s it was estimated that 85% of cattle in Nigeria were kept by Fulani. In the 1970s already more than half of Fulani cattle keepers in Nigeria were 'settled' i.e. occupied a permanent homestead around which the herd was kept year round (Waters-Bayer and Taylor-Powell, 1984a). The remaining Fulani were predominantly transhumant (using certain wet and dry season grazing grounds on a regular basis but having a fixed home base). Only about 5-10% were nomadic, without a fixed home base (Fricke, 1979, van Raay, 1975).

Cattle productivity in the sub-humid zone tends to be lower than in other regions (Mani et al., 1993), due to the long dry season of between 5 and 8 months that impacts on quality and quantity of forage (Mohamed-Saleem and Kaufmann, 1994).

3.1.2 Fulani

3.1.2.1 Origins

The Fulbe pastoralists are widely distributed across West Africa. They are the largest migratory ethnic group in the world and are known by different names: Fulani (from Hausa word) in Nigeria, Fula in the Gambia, Guinea and Sierra Leone; Fellah in Sudan; Fellaata in Kanuri (Chad Basin); Peul or Peulh in Francophone West Africa, with the Woodaabe or Bororo being a subgroup found in southern Niger, northeastern Nigeria and northern Cameroon.

The origin of the Fulani is obscure (Ibrahim, 1966). Legends recounted by elders suggest one of the prophet Mohammed's disciples left the Arabian Peninsula and moved southwest, meeting an African woman en route and the Fulani are believed to be descendants of this union (Awogbade, 1983). The first Fulani settlement has however been traced to the Senegambia, and it is suggested that they moved eastwards in search of pasture for their cattle, passing through Messina and the Hausa States towards Chad, eventually reaching Sudan (Awogbade, 1983).

The Fulani are thought to have reached Nigeria (Hausaland) in the 13th century, by which time they had embraced Islam (Ibrahim, 1966). By the 15th century some Fulani had largely abandoned herding and settled to become scholars and counsellors in the courts of the Hausa rulers (Waters-Bayer and Bayer, 1994). The rest maintained seasonal migration with their herds, relying on the 'settled' elite Fulani to ensure rights of passage and pasture.

In the 19th century, Usman Dan Fodio led a jihad against the Hausa rulers, securing his Fulani leadership and supremacy in much of Northern Nigeria. At this point the tribe divided into a Fulani elite who intermarried with the Hausas and the 'cattle Fulani' or 'Bororo' who continued with their pastoral life (Ibrahim, 1966).

3.1.2.2 Social grouping

In Nigeria today, the Fulani elite and 'Bororo' can be further subdivided into: 1) the elite; 2) settled Fulani (from judges to farmers); 3) semi-sedentary Fulani or

agropastoralists (combined pastoral and cropping activities) and 4) nomadic pastoral Fulani 'Bororo' subsisting entirely on their herds (Stenning, 1957).

The Fulani ethnic group can be firstly divided into 'tribes', the widest social grouping, and are believed to favour particular strains of cattle, or practice a common decoration of milk calabashes (Stenning, 1957). Tribes can be subdivided into kinship groups or 'clans', which anthropologists have defined as the 'collective descendants of a vaguely known historical ancestor' (Bonfiglioli, 1993). Each clan then consists of several lineage groups, formed by the common relationship, through males, of a number of household heads to a common male ancestor three or five generations past (Stenning, 1957). The next subdivision is the family, the basic social and economic and smallest political unit organised around a patrilineal homestead (Bonfiglioli, 1993). The responsibility of herd keeping rests on the household head.

3.1.2.3 Socio-political organisation

The Fulani have a chieftaincy system and have set up organisations to represent their interests. A settled pastoral community will fall under one *Sarkin Fulbe*, elected by District Heads and turbaned in ceremonies performed by the emirs. The District Head is responsible for the appointment of *Ardos* (Village Heads), representing the interests of particular clans. An *Ardo* can inherit title and position from his father (Waters-Bayer and Taylor-Powell, 1984b). The *Ardos* were recruited by the colonial administration to collect the cattle tax (*jangali)* prior to its abolition in 1976. The *Sarkin Fulbe* typically meets with the *Ardos* to discuss concerns, such as on-going disputes about the management and use of pastoral resources (Blench et al., 2006).

The Miyetti Allah Cattle Breeders Association of Nigeria (MACBAN) is a well-established Pastoral Organisation which was set up in 1972 to promote the welfare of Fulani pastoralists and represent their interests before government bodies (Waters-Bayer and Taylor-Powell, 1984b). Its popularity declined when MACBAN leadership was taken over by successive *Sarkin Fulbe* who did not represent the interests of the herders (Blench et al., 2006). The MACBAN movement encourages Fulani to claim their rights through education and settlement but have difficulties in maintaining the commitment of pastoralists who are on the one hand traditionally

very independent in their production activities and on the other more concerned with disease control and land rights (Waters-Bayer and Taylor-Powell, 1984b).

The common heritage and cultural links of Fulani herders with their elite town-dwelling counterparts meant that their interest was represented in politics and that they could influence policy. That influence has gradually diminished as communication channels and links between these two groups have diverged. Thus the welfare of Fulani is now largely neglected by the state and this has led to frustration and conflict (Blench et al., 2006).

3.1.3 Constraints in pastoralism and the origin of conflict

3.1.3.1 Drivers for change

3.1.3.1.1 Disturbance of the system equilibrium

Drivers for change to the pastoral way of life can be broadly grouped into human and environmental factors. These are inter-linked since humans are an integral part of the ecosystem and drivers are sequential and cumulative. Ultimately when a change occurs which disturbs the equilibrium of a system, adaptations are required to enable the system to reach a new equilibrium. The speed of change will impact on the ability of the system to establish equilibrium. Events of the last three decades have brought about very rapid change in Nigeria, creating great disturbance to a previously stable and balanced system.

3.1.3.1.2 The era of 'equilibrium'

Prior to the 1950s, a symbiotic relationship existed between pastoralists, crop farmers and their environment. Pastoralists practised dry season migration to the southern parts of the savannah zone to take advantage of the better pasturage (which they could not do during the wet season because of the greater seasonal dispersal of tsetse infestation in this zone at that time and the associated trypanosomiasis risk both to people and their livestock). The Guinea savannah contained a lower density of crop farmers as soil quality was poor, human trypanosomiasis was a concern and conditions for farming were not as optimal as in the Sudan savannah. Pastoralists' cattle could graze freely and plentifully in vast and safe rangeland, reducing opportunities for their cattle to stray and graze on farmland.

During the wet season, pastoralists returned to the northern zone of the savannah (Sudan savannah, semi-arid zone), cattle benefitted from grazing on the crop residues in harvested fields, while benefiting crop farmers as the cow dung fertilised the fields. Pastoralists often returned to the same fields year after year, developing friendly relations with their owners who they also supplied with milk and yoghurt (Shaw, A., pers. comm.). There was opportunity for trade, both for crop farmers and pastoralists. Pastoralists purchased maize from crop farmers, and the crop farmers purchased milk products from the Fulani women. Even though pastoralists did not own land, they were welcome and encouraged to set-up camp adjacent to crop farming (and land owning) communities, because of the opportunities for fertiliser and milk (Stenning, 1957). The availability of fertilisers reduced this dependence (Waters-Bayer and Bayer, 1994).

The Fulani were politically represented and could seek backing from powerful Fulani emirs to resolve land issues or disputes 'fairly' with indigenous crop farmers. Disputes were resolved through unprejudiced channels (Stenning, 1957).

The above description of the 'equilibrium' sets in context the status quo prior to the current 'chaos'. It is necessary to analyse the drivers that 'pushed' and 'pulled' both the Fulani and crop farmers further south, which led to behaviour change and ultimately disturbed the fragile equilibrium that had previously existed.

3.1.3.1.3 Climate change

Dramatic shifts in climatic conditions have made the northern eco-zones of Nigeria less attractive to both farmers and pastoralists (Blench, 1996). It is estimated that 35% of land that was cultivable 50 years ago is now desert across 11 of Nigeria's northern states and that over 15 million pastoralists are threatened by decreasing access to water and pasture (IRIN, 2009a, Stewart, n.d.). The wet season in northern Nigeria has reduced to an average of 120 days (from 150 days 30 years ago), reducing crop yields by 20% (IRIN, 2009a). Desertification, drought, unpredictable, reduced rainfall, soil exhaustion and infertility has made the northern parts of the Sudan savannah difficult terrain for crop farming and livestock rearing (Azuwike and Enwerem, 2010). This has promoted the shift of both crop farmers and pastoralists farther and further south to the Guinea savannah (sub-humid zones), and even as far

as the guinea forest, as desertification has expanded progressively further south. Land of exploitable value for pastoralists and crop farmers is shrinking at a time when the population of Nigeria is expanding. More people living in a smaller area has led to increased competition for limited resources, leading to conflict.

3.1.3.1.4 Colonisation of subhumid zone and tsetse habitat destruction

The reduced tsetse fly density in the Guinea savannah and rainforest zones (Azuwike and Enwerem, 2010) has resulted in a southward shift of crop farmers and pastoralists. Anthropic factors include improvements in cultivation techniques that compensate for low yields previously obtained in the sub-humid zones, attracting farmers, who progressively cleared forest to make way for farmland (Blench, 1996). Bush clearance and disease control have caused some herders to abandon bases in the semi-arid zone and spend the whole-year round in the subhumid zone (Oxby, 1984).

As the population of Nigeria has increased, previously densely forested Guinea savannah and forest have become deforested. There have been concerted efforts to reduce the tsetse fly population in areas of high tsetse density through aerial spraying and other interventions. Interventions were undertaken to promote the migration of pastoralists and crop farmers to previously human sparse populations to relieve pressure in human dense areas of the north (Oxby, 1984). In 1985 it was estimated that 80% of the cattle kept in the humid zone of southern Nigeria were not trypanotolerant breeds (Akinwumi and Ikpi, 1985). Clearing of previously tsetse-infested land encouraged pastoralists and crop-farmers to stay in the Guinea savannah zones year-round leading to competition for resources (Hardin, 1968).

3.1.3.1.5 Politics and religion

Competition for dwindling resources has fuelled disputes over land. Ethnic and religious differences have been exploited to make a case for ‘supremacy’ as each group has tried to argue the case of having superior settling or land rights.

The predominantly Christian south with a lower population density than the predominantly Muslim north, is more economically rich and benefits from a more established infrastructure (hospitals, schools etc.). The ‘power-house’ of Nigeria in the south, means that even though Christians are a minority in the north, their

interests are promoted at political level, to the frustration of their Muslim counterparts. State revenues are not shared and factional elites have taken control of state institutions, perpetuating the exclusion of certain groups (IDMC, 2009).

In the middle-belt region of the north, autochthonous or indigenous populations from minority tribes are known as the 'indigene'. The Indigene claim supremacy since they have been there the longest and will not cede land to 'settlers' or 'immigrants'. Indigenous groups will prevent settlers from owning land or businesses (IDMC, 2009). Usually, these migrant populations are Christian and a minority in the north, but they have the political backing of the decision-makers of the south. The opposing faction argues that the north is predominantly Muslim and that Islamic faith groups should have priority over land use. At a time when emotions run high and poverty is a daily reality for many, religious leaders are exploiting this malaise to their advantage and giving people an opportunity to vent their frustrations through violent means and acts of terrorism (IRIN, 2009b). The National Planning Commission (2004) has shown a progressively increasing poor population for Nigeria, especially in the north and "*a more vulnerable northern population translates into a more pressurised southern region*." (Azuwike and Enwerem, 2010).

In Jos, three indigenous groups (the largely Christian Burom, Anaguta and Afizere) argue that origin is transcendent when it comes to rights of citizenship. They fear that the Hausa commercial and population dominance will yield them political power (IRIN, 2010c). The Hausa community claim that they cannot secure jobs with the local government due to discrimination.

The Fulani as a group have more or less lost their political voice but they have associated with the Hausa. Fulani generally have less formal education and are therefore badly represented in local government positions (Oxby, 1984).

Decision-makers in the south tend to promote the interests of Christian crop-keepers in the north, neglecting or failing pastoralist interests. When questioned about a recent conflict in Jos an individual stated: "*The state government is very discriminatory in its practices, notably in the exclusion of so-called settlers from state politics, and its views towards the recent violence in Jos are one-sided, defined by religious orientation and ethnic prejudice of those in power*." (IRIN, 2010a).

Government policy has focussed on settling pastoralist populations through the creation of grazing reserves to reduce herders' movements and prevent conflict with crop farmers (Oxby, 1984). The success of the grazing reserves has been poor and the government policy of sedentarisation has done little to resolve conflict between Fulani and crop farmers (Blench, 1996, Oxby, 1984).

3.1.3.1.6 Issues of land-rights

The Fulani's lack of rights to land ownership underpins part of the conflict in Nigeria. Unlike the indigene crop farmers, Fulani do not have rights to ownership or inheritance of pasture, water or cattle tracks (Stenning, 1957). Fulani access to land depends on their relationship with the local indigenes, who invariably claim priority (Oxby, 1984). Discrimination runs deep and land-rights of Fulani who have settled to cultivate land are not considered to be as permanent as those of other farmers, so that Fulani are forced to move out if land becomes scarce (Oxby, 1984). Year-round nomads with no permanent homestead have difficulty in securing access to land as they only visit zones on a seasonal basis (Oxby, 1984). When a dispute between nomads and farmers goes to court, nomads have to pay heavy compensation for the crop-damage (Ibrahim, 1966). The number of grazing reserves, are insufficient to meet the needs of the 15 million pastoralists in northern Nigeria today (IRIN, 2010c).

3.1.3.1.7 Encroachment of transhumance corridors

Transhumance has become a source of confrontation between Fulani and crop farmers, as pastoralists are increasingly obliged to pass through areas of farmland due to diminishing availability of official migration corridors. Farmland is encroaching on the official migration routes originally devised to enable herds to re-join the fadama areas (naturally, usually low-lying, flooded areas) of the south at the onset of the harmattan (Blench, 2010). The lack of government incentives to preserve transhumance corridors prioritises crop farmer's interests over that of pastoralists. Cordoning off of livestock routes in Jigawa state reduced conflicts from 20 to 3 per year in 2009 (IRIN, 2010c), highlighting the link between provision of migration corridors and reduction in conflict. Nomads from Nigeria, Niger, Benin, Cameroon and Senegal all profit from Jigawa's cattle routes (IRIN, 2009a), highlighting the largely ignored issue of influx of nomads from countries bordering Nigeria.

Historically transhumance occurred in bands, with the Nigerian Fulani as the southernmost. During the dry season the Nigerian Fulani would move to the middle belt, some Niger Fulani would replace them, their summer grounds being in turn occupied by Tuareg and other groups (Shaw, A. pers. comm.).

3.1.3.2 The nature of change for the Fulani

Pastoralists have been progressively pushed from the Sudan savannah (semi-arid zone) southwards into the Guinea savannah (subhumid zone), with some having migrated as far south as the southwestern states of Ogun and Oyo. Fulani are now establishing permanent or semi-permanent camps from areas ranging from Jos in the north to areas like Owerri in the south, at the cost of conflict with their farming hosts (Azuwike and Enwerem, 2010). The pull towards the southwest is linked to better market opportunities in this region. Demand for meat is highest in the affluent southwest where most large cattle markets and abattoirs are situated. Fulani selling cattle direct to the abattoirs and markets of the southwest will get better prices, and this has stimulated an influx of Fulani to this area. The pull factor is related to the increased safety in these areas, since most pastoralists settling in the southwest are internally displaced people (IDPs) or refugees. Individuals were either forced to move out of their area of origin in the north by the local authorities in an attempt to prevent further violence and conflict or to flee from outbreaks of violence over election results or from communities divided along religious lines.

"*The Fulani markets of the south are no longer simply places where cattle exchange hands but have now turned into major grazing bases and become havens protecting pastoralists against irate crop farmers*" (Azuwike and Enwerem, 2010).

In Southern Plateau State, 2000 Fulani nomads from Wase were expelled in 2009 by state security forces in 2009 for 'conflict prevention'. There are no official figures on the current number of IDPs (IDMC, 2009). The Civil Rights Congress, which monitors outbreaks of violence, estimated that Nigeria has experienced 670 ethno-religious crises since 1979, leading to 85,000 deaths and displacing over 10 million people (IRIN, 2009b). The status of pastoralists in Nigeria has been changed to that of 'environmental refugees' as a consequence (Azuwike and Enwerem, 2010).

The push southwards has been accompanied by a shift from a livelihood based solely on pastoralism to one incorporating crop farming. A growing number of nomads have abandoned pastoralism and moved to towns and cities for work (IRIN, 2010b). In 1988 it was estimated that the dry season population of over 300,000 cattle in the derived savannah decreased by only about 40% in the wet season (RIM, 1988). This indicates an increasingly stable cattle population exists in the zone and that there is tendency towards sedentarisation among cattle owners. The majority of Fulani are semi-nomadic or semi-settled, have permanent homesteads and will only practice short-range dry and wet season migration- compared to the long distances covered by their predecessors. Azuwike and Enwerem (2010) suggest that the Fulani have "increased spatio-temporal range in the south". This was already well under way by the mid-1970s, where substantial Fulani herds were observed in the Lafia area (Putt et al., 1980, Bourn et al., 2001). A study on the sedentarisation of Fulani cattle-farmers (Jabbar et al., 1995) in five states of southwest Nigeria indicated a process of on-going settlement, with an increasing number giving up wet season migration northwards to become mixed livestock/crop farmers. Sedentarisation has become attractive to nomads as access to rangeland declines, conflict and insecurity worsen and they become alienated from their pastoral lands (Azuwike and Enwerem, 2010).

Distances covered during transhumance (regular seasonal movement of cattle southward in the dry season in response to shortages of pasture and water and northwards in the wet season to avoid tsetse) have reduced, but migratory drift (in response to changes in environmental conditions) has increased as there has been a gradual displacement of customary transhumance tracks and orbits southwards (Stenning, 1957). Political flight from intolerable conditions of a political or ideological nature has also increased, as Fulani are moving away from the violent clashes of the north towards the south or into grazing reserves.

Southward movement of Fulani pastoralists has been a feature of the last 4 decades, throughout West Africa. The Sahel droughts that peaked in 1973 and 1984 were an important causal factor. The most notable shifts (apart from Nigeria) were to the northern Côte d'Ivoire and the Central African Republic where large populations of Zebu cattle now live in tsetse-infested zones that they had not previously inhabited.

And the droughts caused other northern pastoral tribes like the Tuareg to move further south (Shaw, A., pers. comm.).

3.1.4 Grazing reserves

The concept of Grazing Reserves emerged as a policy tool in the 1960s to address two priorities: 1) develop or modernise the livestock sector, improve livestock productivity and move away from traditional cattle-rearing and 2) reduce clashes between pastoralists and crop farmers surrounding land-rights issues and competition for resources by giving Fulani more secure land tenure. This concept was not new, however, as preserving rangeland for the exclusive use of livestock was already undertaken in colonial times (Waters-Bayer and Taylor-Powell, 1984b). The stated purpose of Grazing Reserves is the settlement of nomadic pastoralists (Suleiman, 1986). The sedentarisation of nomadic populations has its proponents and opponents.

3.1.4.1 The development of grazing reserves

The Nigerian Government passed the Grazing Reserve Act in 1965 (Waters-Bayer and Taylor-Powell, 1984a, Awogbade, 1987, Ingawa et al., 1989). During the third National Development Plans (1970-1980), the federal and state governments made a 120 million Naira investment in livestock development, of which 70% was allocated for grazing reserves. Livestock development and the establishment of grazing reserves was largely implemented through the National Livestock Project Unit (NLPU), part of the Federal Livestock Department which today is called the National Livestock Project Department (NLPD) (Ingawa et al., 1989). The NLPD was also responsible for the provision of infrastructure such as boreholes, dams, schools, roads etc. The absence of formal gazetting (in KGR this did not occur until 1996), the absence of legalised grazing and land ownership and slow government investment and development in infrastructure dissuaded pastoralists from settling in grazing reserves (Waters-Bayer and Taylor-Powell, 1984a).

The selection and acquisition of grazing lands is the responsibility of individual states. The Federal Land Use Act of 1978, with its recommended high levels for land compensation has dissuaded many states from acquiring land for the setting-up of grazing reserves (Waters-Bayer and Taylor-Powell, 1984a). In 1981, the Ministry of Agriculture declared that 22 million ha were to be converted to grazing reserves, but

only 2.3 million ha had been acquired by 1980 (Oxby, 1982). Today, Nigeria officially has 415 grazing reserves but only one-third are in use as the remaining 270 have been established on farmland and have not been gazetted (IRIN, 2009a).

3.1.4.2 The Kachia Grazing Reserve

3.1.4.2.1 Origin

Kachia grazing reserve (KGR), was established by the Kaduna State Ministry of Animal and Forest Resources in 1967 (Waters-Bayer and Taylor-Powell, 1984a). Developmental work for the reserve did not commence until the late 70s, when the Ministry of Agriculture were assigned to map out strategies for water and pasture development. KGR was re-officialised in 1988. KGR was not gazetted until 1996.

3.1.4.2.2 Location and topography

KGR is 33,411 ha in size and situated between Kufana in Chikun Local Government (LG), Kachia in Kachia LG and Kamuru Ikulu in Zangon-Kataf LG. KGR lies north and west of major migration routes followed by transhumant Fulani based in the Kano and Bauchi areas (Waters-Bayer and Taylor-Powell, 1984a). KGR is relatively flat and is covered with tree savannah and shrub.

3.1.4.2.3 Stated aims of KGR

KGR, was established to: 1) settle the nomads in one location so as to improve their standard of living; 2) improve the quality of livestock production, 3) to reduce or control conflicts between nomads and farmers; and 4) to serve as a research area.

3.1.4.2.4 ILCA Sub-humid Zone Programme

KGR, then referred to as the Kurmin Biri case study area (Figure 14), was chosen as one of the study areas as part of a large research programme commissioned by the International Livestock Centre for Africa (ILCA) in 1978, which focused on livestock production in the sub-humid zone. At this time, the Fulani were concentrated in a relatively small area close to the administrative camp in the southeast corner of the reserve (Figure 14). In 1984, 34 Fulani households were recorded to have settled in the KGR. None of these settlers, however, were previously nomadic, and they considered themselves indigenous to the area and

farmed food crops around their settlement in the reserve (Oxby, 1984). Transhumant Fulani also visited KGR, branching off from their transhumance route to use the KGR for dry-season grazing (Waters-Bayer and Taylor-Powell, 1984a).

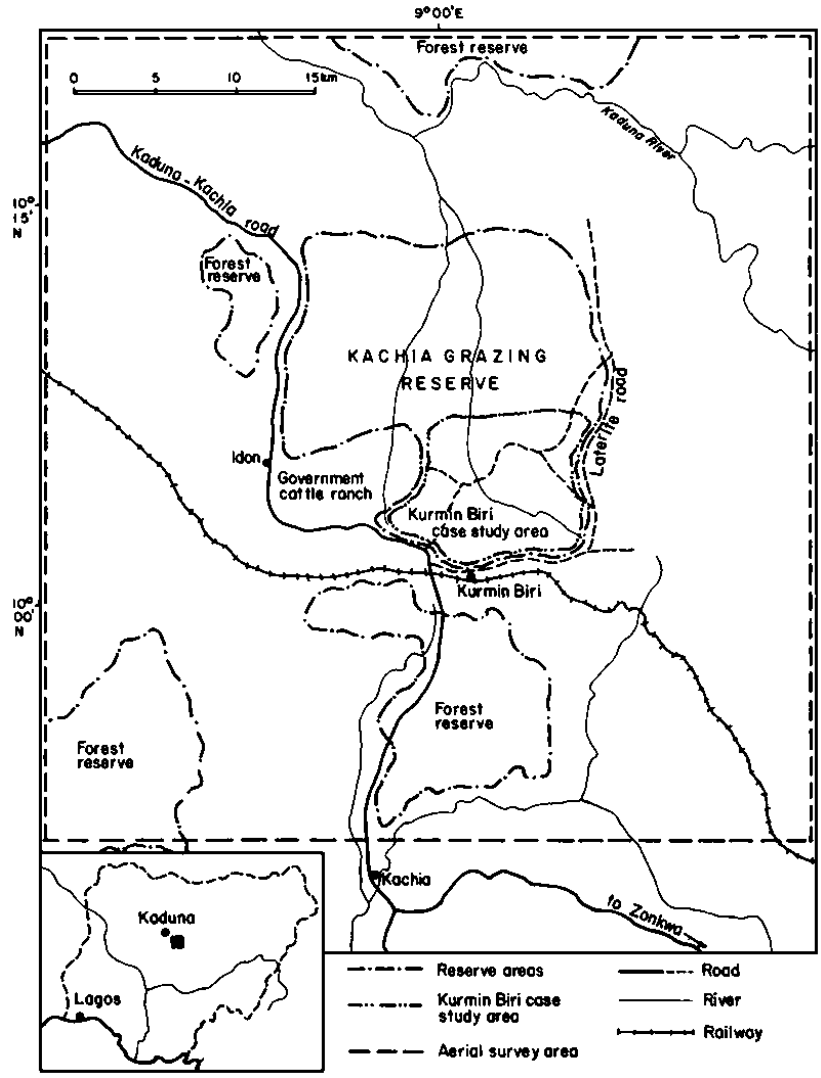


Figure 14 Location of Kurmin Biri case study area, note that households in KGR were at that time located in the southeast (Waters-Bayer and Taylor-Powell, 1984a)

3.1.4.2.5 State administration of the KGR

The State Ministry of Agriculture administrative office runs the general administrative activities of the reserve, headed by the Project Officer who has a supervisory role and writes monthly updates. Officially (as stated in the gazette) any person wishing to bring any animal into KGR should obtain a permit to do so from the Project Officer. The permit will then specify the number and type of animals

permitted to be in the reserve, where they are permitted to graze, the size of the area allocated for grazing and a photograph of the person in whose name it is issued. A fee is payable for such a permit and must be renewed annually.

3.1.4.2.6 Traditional institutions within KGR

KGR settlers refer to the district of KGR as 'Ladduga' or 'forest' in Fulfulde. The headquarters and trading centre of Ladduga district are at Wuro Fulbe (village of Block 2), popularly known as 'Tampol' (when shops in the market area were erected from tarpaulin, and with the presence of researchers in KGR for a World Bank project, 'tarpaulin' was transformed to 'Tampol') (Figure 15). Ladduga is under Ikulu Chiefdom in Zangon-Kataf LGA, Kaduna State. The district has 9 *Ardos* (Village Heads). Each *Ardo* represents a clan. Nomads have settled according to clans. Each settlement area has been named according to the name of the clan elder, and the names of the various villages of KGR are: 1) Wuro Nyako; 2) Nassarawa; 3) Wuro Fulbe; 4) Wuro Saleh; 5) Tilde Bayero; 6) Mayo Jamil; 7) Mayo Borno; 8) Wuro Modi; 9) Margire; and 10) Giyja. KGR is divided into 6 blocks (Figure 15).

3.1.4.2.7 Services, amenities and infrastructure within KGR

At inception in 1967, KGR was sprayed with insecticide and declared tsetse-free. In the 1980s, efforts to encourage the settling of Fulani included the building of administrative headquarters, roads, dams and cattle dips. The Federal Livestock Department, NLPU and ILCA were involved in developing a farmer centre, credit scheme, veterinary service, bore wells and experimentation with various methods of pasture improvement as well as a smallholder dairy scheme supplying supplementary cattle feed on credit. The programme was largely funded by the World Bank, through NLPU, and included 24 staff (a range management officer and his assistant, four grazing control assistants, a veterinary assistant, one typist, one driver, three plant operators, five permanent and five casual labourers, and two watchmen) (Oxby, 1984). When funding stopped none of the amenities and services were maintained.

Amenities today include a secondary school located near the Livestock Training Centre just outside of the reserve, but not within easy walking distance. Officially nine primary schools have been built under the Ministry of Education. Since these

are now for the most part dilapidated and there is a shortage of teachers, only Block 2 provides schooling. Koranic schooling is organised at village level by the community members. A Vocational Training Centre was under construction in 2011 from the National Commission for Nomadic Education, Agriculture Development Fund.

KGR has a community health clinic supported by Pastoral Resolve (PARE) and Pathfinder International (NGOs) that relies on volunteers with basic health training. KGR also has a private medical clinic established by a KGR community member who returned to Ladduga to provide medical care to this neglected community.

A veterinary clinic was constructed at Wuro Nyako by NGO Nomadic Education but with no drugs or paravets has since ceased to function. The Project Office/Training centre at the entrance of the KGR also used to provide a veterinary service, but of the 24 staff posted in the KGR during the ILCA/LPU project, only one Project Officer/paravet remains with no transport. KADP constructed a milk collection unit situated at Tampol under the Commercial Agriculture World Bank intervention programme. This facility was completed years ago but has not been commissioned.

The KGR was equipped with thirteen earth dams and fifteen bore holes but a large number of these dams have ceased to function. There are two major roads linking the reserve to the major Kafanchan-Kaduna road, which are not tarmacked and are in very poor condition. Within the reserve there are other network access roads, also in poor condition, especially during the wet season.

The commercial hub of KGR is at Tampol where there are numerous shops, including teashops, butchers' shops etc. Every Friday, traders from other villages come in and set up stalls to sell food items, clothes and other products.

3.2 Analysis of human and livestock population and dynamics

3.2.1 Introduction

In this section data from two separate population censuses is presented. The censuses involved collection of demographic data (see materials and methods) from every household resident within KGR. The census in July 2010, was undertaken by the KGR Project Office (State Government). This data was used as the sampling frame for the March epidemiological survey (Chapter 8 and 11). A second epidemiological

survey was undertaken in June to repeat brucellosis screening (in March many households had taken their herds out of KGR for dry season transhumance).

When the field team returned to KGR in June was clear that there had been mass immigration of Fulani households and that the July 2010 sampling frame was no longer valid. Informal interviews with the Red Cross (present on the ground to give out bedding and food to the refugees) confirmed that there had been a huge influx of internally displaced persons (IDPs) in April-May 2011 as a result of violence related to the general elections of April 2011 (IFRC, 2011). A second census was undertaken in June 2011 to generate a new sampling frame for the June epidemiological surveys.

The census of July 2010, was undertaken by the Project Officer (Habila Gadoh) as part of State government activities. The author of this thesis undertook the June 2011 census with the assistance of Habila and a local guide, Suleiman Yamusa. During the census fieldwork and through discussions with Habila and Suleiman as well as the KGR inhabitants themselves, it became clear that demographic characteristics (number of livestock owned, household size etc.) of KGR households varied across blocks. The six blocks of KGR were thought to be purely administrative units, yet field observations revealed that where households settle within KGR is not random.

Another field observation was that the new immigrant families, which had just settled in KGR in May 2011, were different in terms of size and livestock ownership to households that had settled in KGR for a longer period.

3.2.1 Aims and objectives

Objectives of this study include exploring the hypothesis that household demographic characteristics vary across blocks and that choosing a location for settlement is not a random process. It is hypothesised that household location is related to household ranking in Fulani society, which may be determined by wealth (in pastoralist communities related to livestock ownership- see Chapter 3 for more information), or related to priority over other households based on the length of time settled in the KGR. To explore this, the number of people moving into different blocks over time is investigated. The objective is to identify WHY people chose to settle in a particular zone of the KGR and the drivers that influence settling patterns.

New immigrant households are hypothesised to present different characteristics to households that have been living in KGR for longer periods. New immigrants, defined as households that moved to the KGR in May 2011, are examined as a separate group to explore factors influencing differences between those households and those that settled in 2010 or before, the objective being to compare characteristics of long-time KGR settlers versus new immigrants (important for interpretation of March and June 2011 household questionnaires).

The change in cattle herd size over time since settling in the KGR is also explored. One objective is to explore if herd size reduces with time settled in the KGR. Another objective is to quantify the extent of the mass immigration event of May 2011: how many households, people and livestock moved in to the KGR at this time? This specific immigration event is also compared to previous peaks in immigration and findings discussed within the broader context of political events and unrest in the region. The correlation between household size and number of livestock owned is investigated. The origin of households prior to their move to the KGR is mapped to explore where households resident in KGR have come from.

Investigation of household immigration and settling patterns raises issues as to the drivers influencing emigration, immigration and sedentarisation. Specifically, the reasons why people move to grazing reserves are explored. In broader terms the drivers for pastoralist migration to grazing reserves lie within the context of trends in livelihood change, political instability and conflict in Nigeria, linking the information presented in the previous section with the census data collected as part of this study.

Changing population dynamics drive disease emergence and saturation of the carrying capacity of ecosystems in which these ‘refugees’ settle. Mass immigration of humans and animals originating from diverse areas disturbs the equilibrium of ecosystems and may generate opportunities for disease transmission. Pastoralist populations cannot continue to grow due to limitations in the carrying capacity of the environment of grazing reserves. An awareness of immigration patterns into grazing reserves is relevant for implementation of disease control policy or policy aimed at reducing conflict between pastoralist and indigene populations (Sutter, 1987).

3.2.2 Materials and methods

3.2.2.1 Census study design

Two censuses were undertaken: one in July 2010 and another in June 2011. The reason for undertaking a second census in June 2011 was due to the mass immigration event of May 2011. The censuses were designed and commissioned by the Nigerian State government (http://www.population.gov.ng).

Fieldwork for the July 2010 and June 2011 censuses was organised and led by the KGR Project Officer, Habila Gadoh, with10 years experience of working in KGR and whose role has been to conduct an annual census for the State government. To ensure no households were missed, a KGR community member, Suleiman Yamusa, was recruited as a local guide and assistant. Households were reached on motorbike or foot. Householders return to KGR at the onset of the rains in June, hence both censuses coincided with a period when all households have returned to the KGR even if they practice dry or wet season transhumance.

A *wuro* refers to the extended household or multiple *'ruga'* (homesteads), consisting of a collection of huts belonging to members of the same family. This unit represents a cattle-owning entity headed by the HHH even though individual cattle may belong to different family members. For both censuses, households were defined as individual *ruga,* consisting of a man, his wife or wives, unmarried children and dependent parents, as the unit of interest for the government (see Chapter 4 for household composition). In this section the term household corresponds to a *ruga*.

The approach for locating households was to visit the *Ardo* of each village to seek permission for access. The *Ardo* escorted the census team to every household in his village, ensuring that no households were missed. Householders were briefed and reassured by the *Ardo* on the nature of the census and encouraged to participate. The non-response rate for both censuses was low. During the 2010 census no household refused to participate (some did not answer all questions: 4 households did not give data on number of children and 2 households did not give data on number of sheep and goats). During the 2011 census, the non-response rate was higher (27 households of 777 refused to participate). June 2011 corresponded to a period of post-election

violence: many Fulani were killed and others sought refuge in the KGR, which may explain the reticence of some households to provide personal information.

The household head was the respondent of choice, followed by the next most senior male in the HH. If all men were absent, the most senior woman was interviewed. Men have more accurate knowledge of cattle numbers (although not necessarily sheep and goats often owned by junior household males and women respectively). Data were recorded by hand on a specially designed form.

3.2.2.2 Data collected

Demographic data were collected in answer to the following questions:

- Where did the household originate from before it moved to KGR?
- In which year (and month if known) did the household move to KGR?
- How many wives does the household head have?
- How many children live in the household?
- How many people in total live in the household? (Calculated by adding number of children, wives and HHH as best estimate if no value was given)
- How many cattle, sheep and goats does your household own? (Livestock ownership in Fulani culture is explored in more detail in Chapter 4)
- Are cattle taken on transhumance out of the KGR during the wet and/or dry season? (June 2011 census only)

All households in the reserve were geo-referenced by GPS (Garmin Geko™). The block number and village name was also recorded. Unfortunately for the 2010 census, no distinction was made between Block 5 and 6. Because of the different characteristics of the two blocks, however, Blocks 5 and 6 were differentiated for the 2011 census as per the recommendations of the author of the thesis.

Qualitative data was collected during a FGD and KIIs. A FGD was conducted in June 2011 with *Ardos* from all blocks to discuss immigration patterns into KGR over time and the differences between the blocks in terms of household and topographical characteristics. A KII, broadly discussing past and future trends in KGR, was undertaken with an elderly, educated and elite male member of the community, and our local guide Suleiman Yamusa, a young pastoralist. The following topics were probed into during the FGD and KIIs:

Historical trend analysis

1. What are the major events that have impacted on your community in the last 40 years?
2. Why do people move to the KGR?
3. Where do they come from?

Community profiling

1. Why do households settle in specific blocks/villages/areas?
2. Who decides which household settles where?
3. Are there differences between the households of different blocks?
4. What are these differences and why do they matter? (Prompts: herd size, household size)
3. Are there any differences between the new immigrant households and those that have been settled in the KGR for longer?

3.2.2.3 Data entry and analysis

3.2.2.3.1 Data quality

Data from the July 2010 census were entered in Excel by Habila Gadoh. Strategies employed for quality management of the July 2010 data could not be verified. Data from June 2011 were entered in Excel by this author and (i) Data were profiled to discover inconsistencies or anomalies; ii) Data cleansing was performed by removing outliers found to be entry errors, checking for missing fields, and homogenising common answers entered with different spellings; iii) Completeness and precision checks were performed on data by cross-checking handwritten form data with Excel spread sheet data. This was undertaken once, by this author and a second time by a fellow PhD colleague.

3.2.2.3.2 Descriptive statistics

All data presented in this chapter are census data hence significance tests or calculation of confidence intervals are redundant. Data were analysed using descriptive statistics by plotting frequency histograms (to determine most common household/herd/flock size), bar charts (to contrast number of households across different variables such as block number) and line charts (to examine the change in human and animal populations over time).

The five point summary (minimum, lower quartile, median, upper quartile, maximum) of humans and livestock per household across blocks and for households that moved to KGR during different time periods were compared through plotting of box and whisker plots in R and Minitab®. The box is divided at the median value and shows the interquartile range (25^{th} and 75^{th} percentiles) as a box. Whiskers are calculated as the upper/lower quartile plus 1.5 times the interquartile range. This 1.5 times the interquartile range is known as the step. Beyond the whiskers are outliers, which are shown as points. A boxplot also gives an indication of the symmetry and skewedness of the distribution. Outliers are defined as points that appear to lie outside the distribution of the rest of the data. If an outlier is a genuine result, it is important because it might indicate an important extreme value. In some cases, where the existence of important outliers reduced the size of the box and made the graphs difficult to interpret, a second boxplot showing a subset of more typical, smaller herds was presented (for cattle, sheep and goat ownership per household). Boxplots were constructed in Minitab and are identical to those generated in R except for the fact that the mean and median connect lines are plotted.

3.2.2.3.3 Correlation and regression

Scatterplots investigate relationships between continuous variables. Correlation coefficients (Pearson's and Spearman's rank) were computed in Minitab to assess whether variables were linearly related. A least squares regression was fitted to the scatterplots to examine the relationship between the response and predictor variable. Using Minitab, three model orders were used to reflect all possible trends in the data:

First order: Linear ($Y = b_o + b_1X$)
Second order: Quadratic ($Y = b_o + b_1X + b_{11}X^2$)
Third order: Cubic ($Y = b_o + b_1X + b_{11}X^2 + b_{111}X^3$)

Each model order corresponds with the degree of the equation (the highest power of the X-variable) used to generate the model, where Y is the response, X is the predictor, b_o is the intercept, and b_1, b_{11}, and b_{111} are the coefficients. Simple linear regression was used to explore the statistical relationship between a predictor and response variable. This was undertaken in Minitab using the ordinary least squares method, which derives the equation by minimizing the sum of the squared residuals.

3.2.2.3.4 Mapping of household origin

The location of origin of KGR households was mapped (Figure 35 and Figure 36). All the lines on the map lead to the location of KGR. Place names given varied from focal to wide and could consist of the name of the village, the closest town, district, LGA or even State. When the name of a state was given, the largest town in the state has been mapped as the origin. Place names and their GPS coordinates were verified by Nigerian colleagues with experience of working with Fulani communities in northern Nigeria. The location of origin of four households (Kayalla, Maro, Danga, and Katur) could not be traced and were not mapped. Maps were created in ArcMap 10.1 and show two layers (i) a point layer representing the villages where migrated households come from and (ii) a line layer that connects those villages with the KGR. The symbol size of the point layer is proportional to the number of households that migrated to the KGR and the line length represents the distance travelled.

3.2.2.3.5 FGDs and KIIs

Qualitative research was conducted in Fufulde or Hausa, transcribed in English and then analysed manually based on coding textual data into selected themes and sub-themes. For specifics on how FGDs and KIIs were conducted see Chapter 2.

3.2.2.3.6 Ethical approval

Activities were approved by the KGR Project Office (State Government) and the community leaders (District Head, Village Heads and Imams). Verbal informed consent was obtained from study participants.

3.2.3 Results

3.2.3.1 Household location and immigration

The location of new immigrant households (HH which moved into KGR in May 2011) and settled households (HH which moved into KGR before May 2011) is shown in Figure 15. The most southern zone of the grazing reserve is uninhabited due to heavy forestation and hilly terrain. The number of households in KGR increased from 581 to 777 households in the 11 months between the 2010 and 2011 censuses. Most new households moved into KGR in May 2011. The percentage increase in the overall human, cattle and sheep population between the 2010 and

2011 was approximately 75% for each species. The overall goat population, however, fell by 5%. The human, cattle, sheep and goat population for the KGR in June 2011 was approximately 10,000; 40,000; 10,000 and 5,000 respectively (Figure 16). Block 2 is the most populated block.

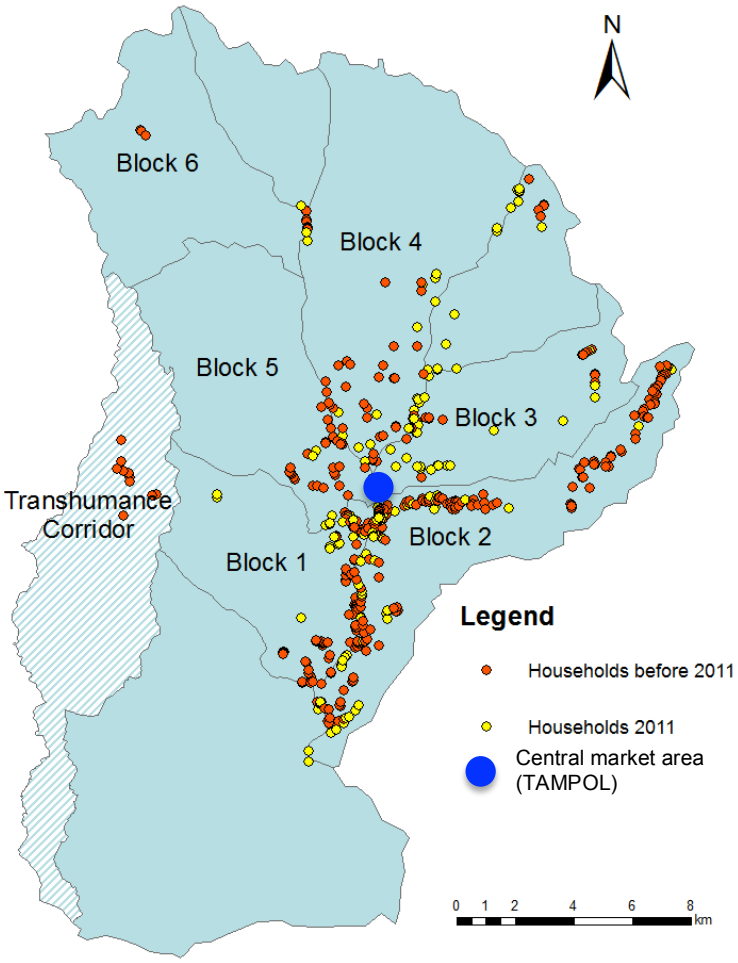


Figure 15 Location of households which settled in the KGR in May 2011 (yellow dots), households which settled into KGR before May 2011 (red dots) and the central market area of Tampol (map credit Ward Bryssinckx)

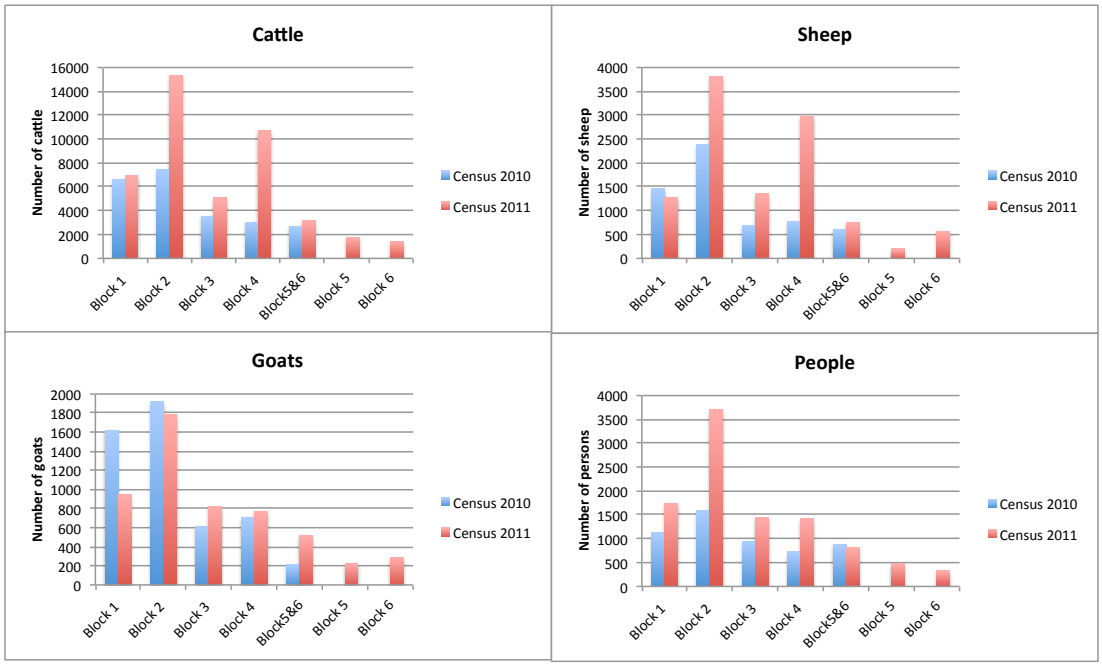


Figure 16 Number of cattle (top left), sheep (top right), goats (bottom left) and people (bottom right) inhabiting/owned by the households of Blocks 1 to 6 as per 2010 and 2011 census

3.2.3.2 KGR human and livestock population increase over time

The increase in the human, cattle, sheep and goat population in the KGR over time was calculated by adding up census data from households who reported moving to the KGR between 1978 and 2011 for each year, putting the years in ascending order, and performing cumulative addition from 1978 to 2011. Data have been plotted for the 2011 census (Figure 17) and are a 'proxy' for the number of households moving in to KGR over time (census data do not capture number of households that moved into KGR but left before census). FGDs indicated very few people left once they had settled in KGR. Grazing licenses are not available to complement this information as the KGR Project Office stopped issuing licences in the 1990s due to under-staffing.

Human, sheep and goat populations have increased at the same rate, whereas cattle numbers have increased more steeply. Population growth was highest in 2011.

The cumulative increase in number of households was also evaluated for the different blocks. Figure 18 shows that the number of Block 2 households has been growing steeply since the first settlers arrived in 1978 whereas other block have been increasing in size more steadily. Figure 19 shows the number of households moving

into the KGR each year from 1978 and 2011, and demonstrates peak immigration in 1990, 1992, 2001, 2007-2010 and a large influx in 2011.

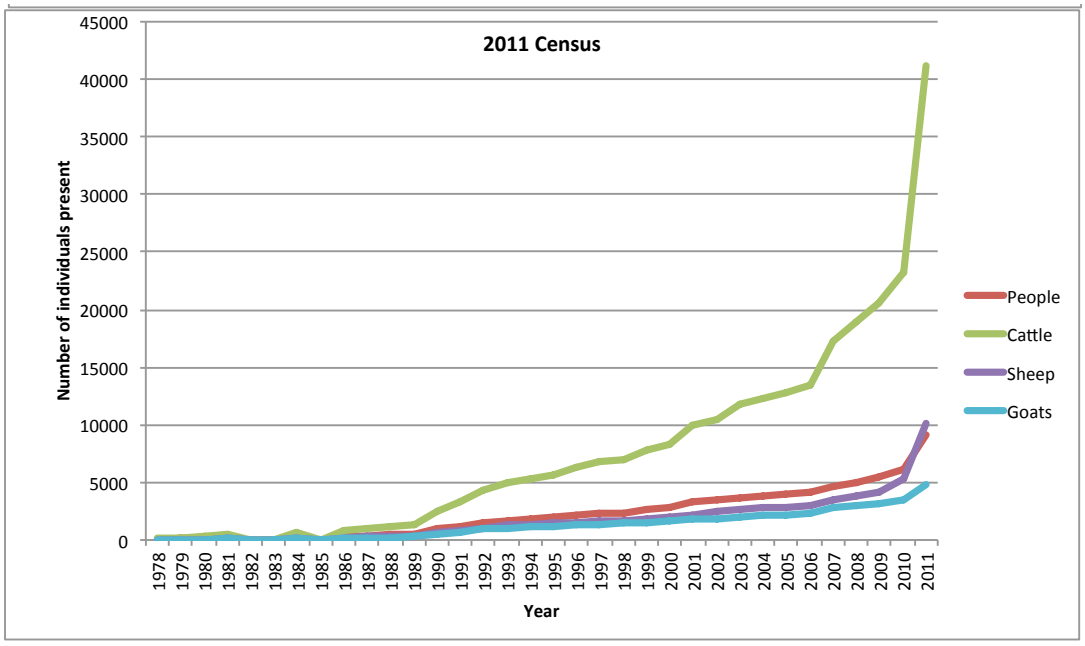


Figure 17 Human and livestock population increase (based on year of arrival to KGR as given by 2011 census)

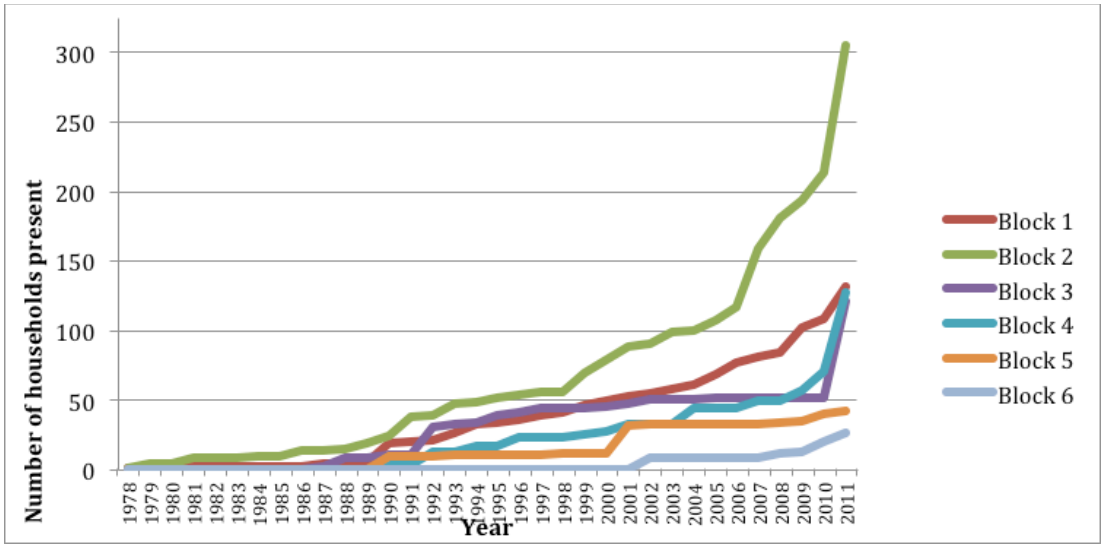


Figure 18 Number of households present by block from 1978- 2011 (based on year of arrival as given in the 2011 census)

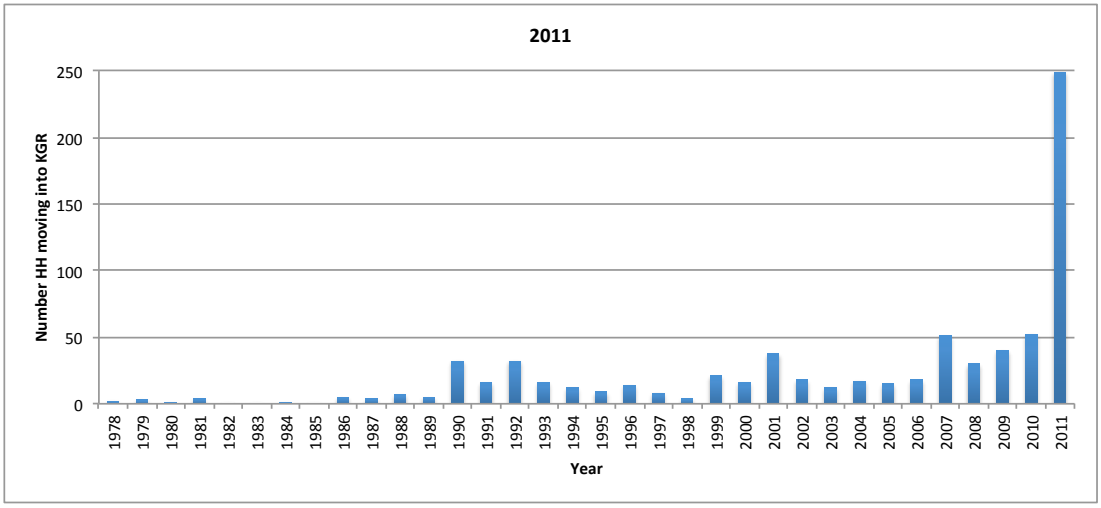


Figure 19 Number of households moving in the KGR each year, 2011 census

The first households settled in KGR in 1978. A frequency histogram was plotted for households that moved between 1978 and 1990, 1991 and 2000, 2001 and 2009, 2010 and 2011 (Figure 20). The rationale for determining the frequency of households for 2010 and 2011 separately is because mass immigration into the KGR occurred in May 2011. Emigration before 2010 was confirmed to have been minimal during FGDs and KIIs: *"once a family moves into the KGR they rarely leave"*.

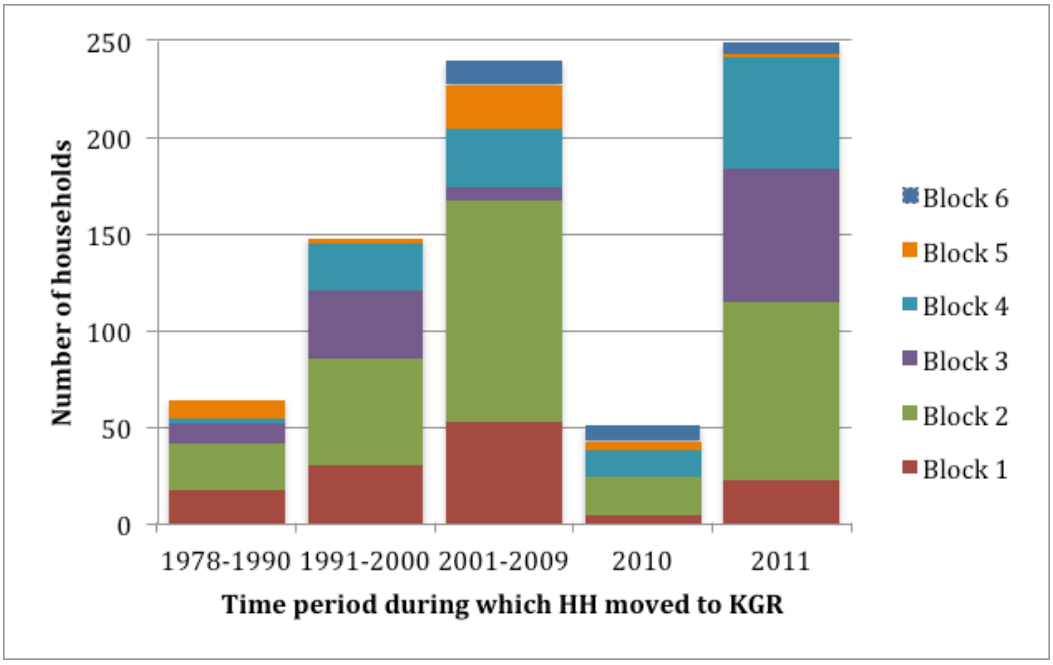


Figure 20 Number of households which settled in KGR between 1978-1990, 1991-2000 or in 2010 and 2011; and block in which they settled for each time period

3.2.3.3 Number of wives

The number of wives of the household head and number of persons in each household were compared across the blocks. The number of wives and livestock (especially cattle) are proxy indicators for the wealth status of a household. Most household heads in the 2010 census across all blocks had only one wife, followed by 2 wives. Few households had three wives or more. Blocks 5, 6 and 1 had the highest percentage of household heads with 3 or 4 wives. Only Block 2 and Block 4 had households where the household head had no wives (Figure 21). Differences in numbers of wives number between the 2010 and 2011 censuses show a higher percentage of household heads with two wives, especially for Blocks 1 and 5 where more household heads have 2 wives than 1. Block 1 has the highest percentage of household heads with three or more wives, but Blocks 3, 4 and 2 also have a higher percentage of more than 2 wife households. Blocks 3 and 4 have a low percentage of household heads with no wives (Figure 22).

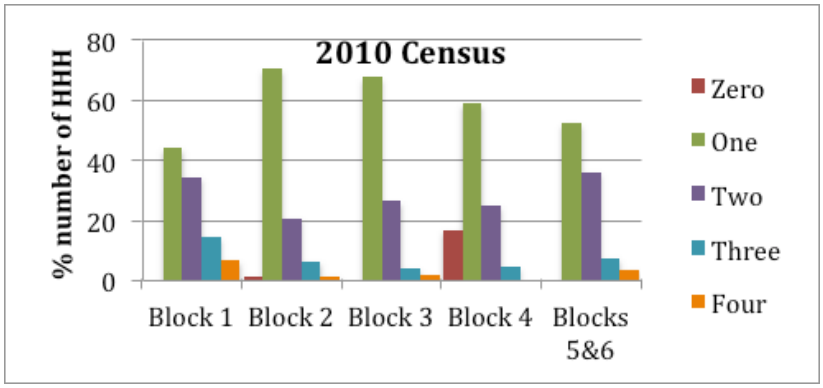


Figure 21 Percentage of household heads with 0, 1, 2, 3 or 4 wives by block, 2010 Census

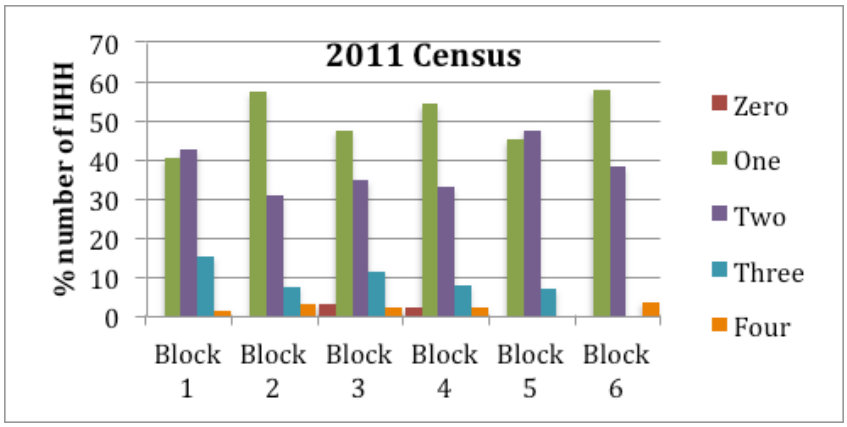


Figure 22 Percentage of 0, 1, 2, 3 and 4 wife households by block in the KGR, 2011 census

3.2.3.4 Household size

The distribution of number of persons per household is negatively skewed with most households being made up of 6 to 10 persons (Figure 23).

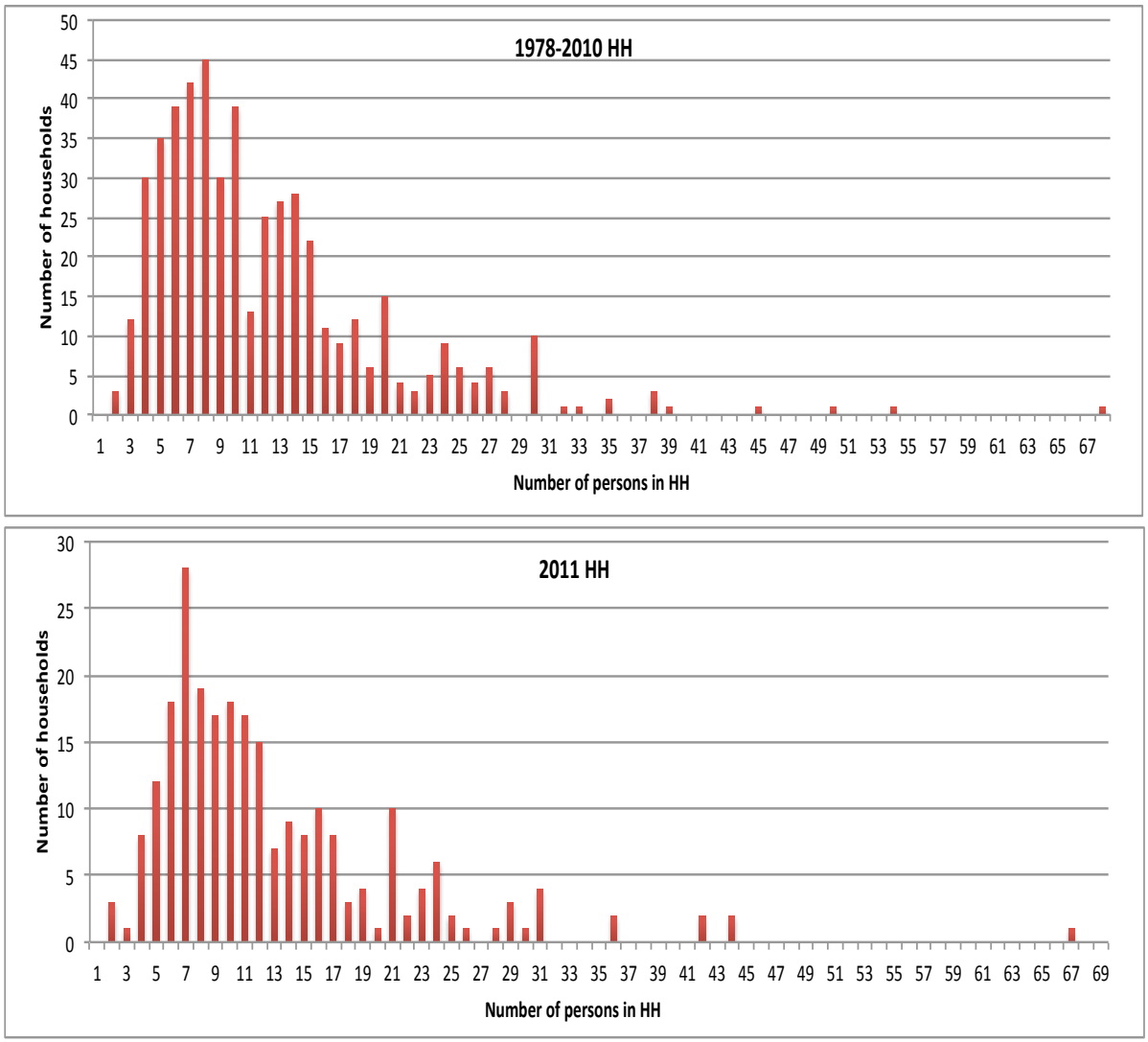


Figure 23 Number of households with 1 to 68 persons in household for households that moved to KGR 1978-2010 (top panel) and 2011 (bottom panel)

Block 1 and Blocks 5 and 6 combined/Block 6 for both censuses have the highest median number of persons per household after which come the roughly equivalent medians of Blocks 2, 3 and 4 (Figure 24).

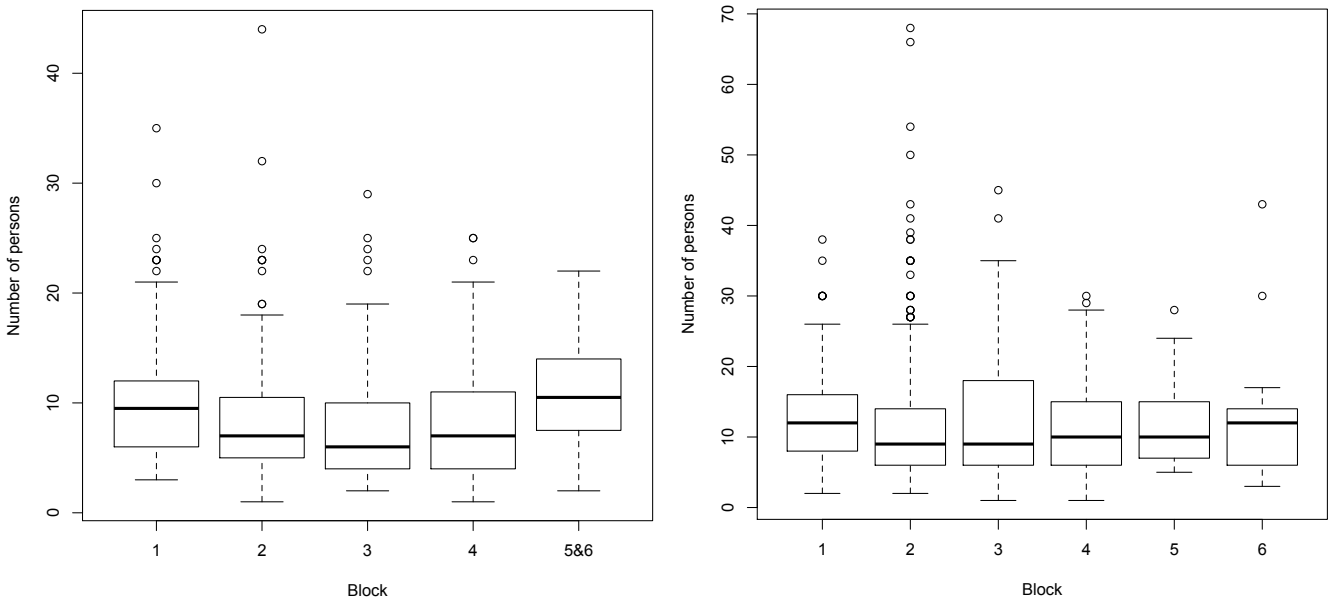


Figure 24 Number of persons per household for 2010 (left) and 2011 (right) census

3.2.3.5 Livestock ownership

The cattle distribution of cattle herd size, sheep flock size and goat herd size is represented in Figure 25. The cattle size distribution is negatively skewed and follows the same pattern for both households that moved to KGR between 1979 and 2010 (old settlers) and those that moved in 2011 (new immigrants). The main difference is that there are more extreme values (herds over 300 cattle) for the new immigrant household category.

A large number of households did not own sheep or goats (250 [34.6%] and 300 [41.5%] households respectively). A lower percentage of new immigrant households (24.1%) did not own sheep as compared to old settlers (36.5%). The opposite is found for goat ownership, with 49.4% of new immigrant households not owning goats as compared to 37.8% for old settlers.

The median number of cattle owned per household for the 2010 census follows the trend observed for the number of persons per household (Figure 26). To compare pattern of medians for the 2011 census, a separate boxplot was created for herds that own 300 or less animals (Figure 26), as the existence of an extreme value (2000 cattle per household) makes the boxplot for the 2011 census impossible to interpret (Figure 26). The 2011 data contain more extreme values than the 2010 census.

The median number of sheep per household in the 2010 census follows the trend observed for cattle (Figure 27). The 2011 census shows that Block 6 has the highest median, with Blocks 1, 2, 3 and 4 having a median around 10, and Block 5 showing the lowest median (Figure 27). Block 4 has a high upper quartile value, showing more spread. Block 4 has an extreme value of 1000 sheep per household (Figure 27).

For the 2010 census, Block 1 has the highest upper quartile for number of goats owned per household, but the median number is similar to Blocks 2 and 3. Blocks 3 and 5&6 have the second lowest and lowest medians (Figure 28). The pattern changes in the 2011 census with Block 6 having the highest upper quartile and median. Blocks 1 and 3 come second in median ranking, with Blocks 2 and 4 third and Block 5 last (Figure 28). There is an extreme value of 150 goats for a household in Block two, and all blocks have outliers except Block 6 (Figure 28).

3.2.3.6 Relationship between herd/flock size and household size

3.2.3.6.1 Correlation

Data from the 2011 census were analysed to explore correlation between livestock herd/flock size and household size. There is weak positive linear correlation between the number of persons living in a household and the number of cattle owned by a household (Figure 29). The Pearson's and Spearman's rank correlation coefficient were found to be 0.273 and 0.361 respectively. Calculation of correlation coefficients excluding outliers (herds of more than 500 cattle) only marginally increased the correlation coefficients. Correlation coefficients between household size and sheep flock size, household size and goat herd size, cattle herd size and sheep flock size and cattle herd size and goat herd size were investigated and were all found to be around 0, indicating that there is no linear relationship between these variables.

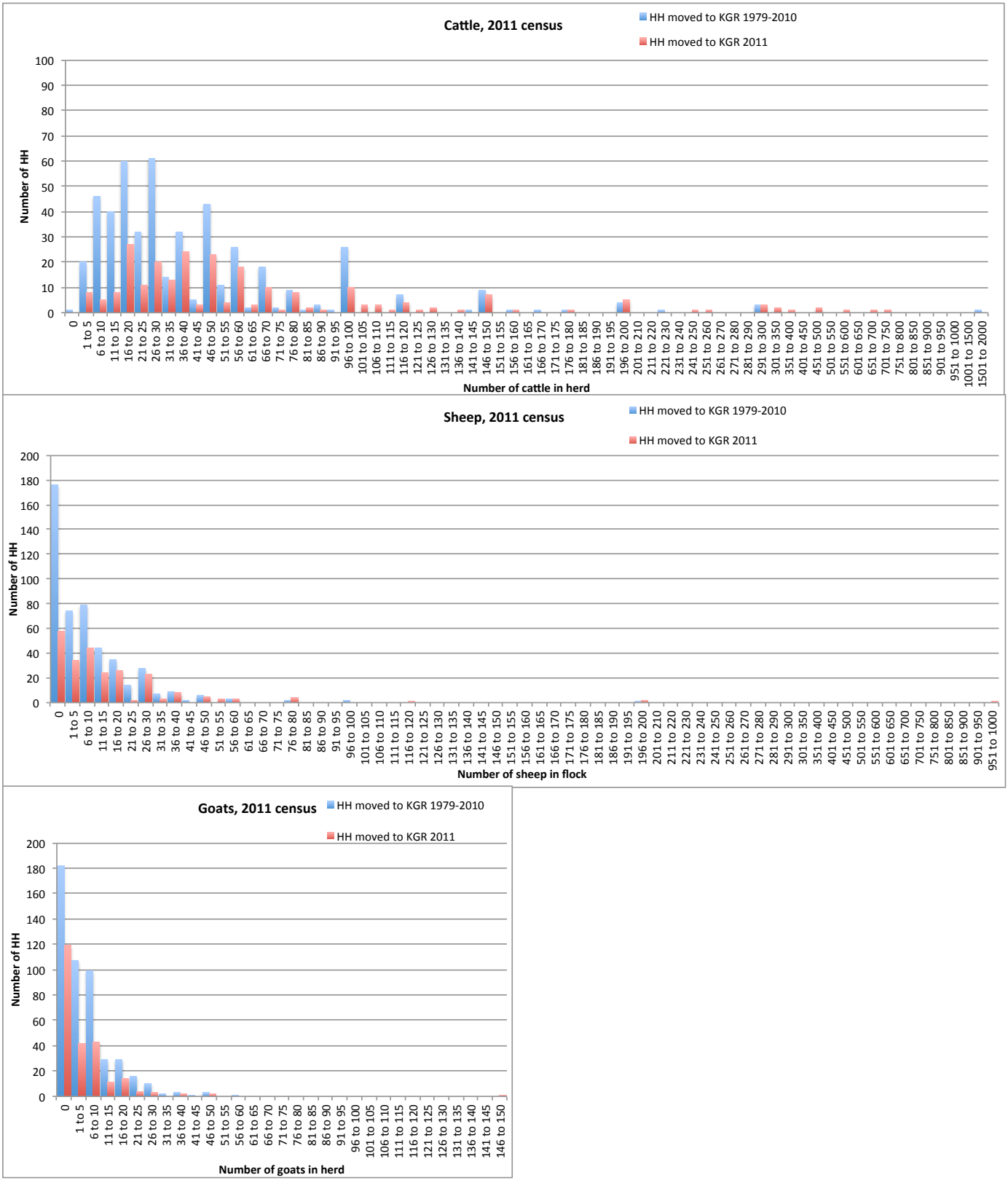


Figure 25 Frequency histogram of cattle herd size (top panel), sheep flock size (middle panel) and goat herd size (bottom panel) for households that moved to KGR between 1979 and 2010 and for new immigrants that moved to the KGR in 2011, based on 2011 census

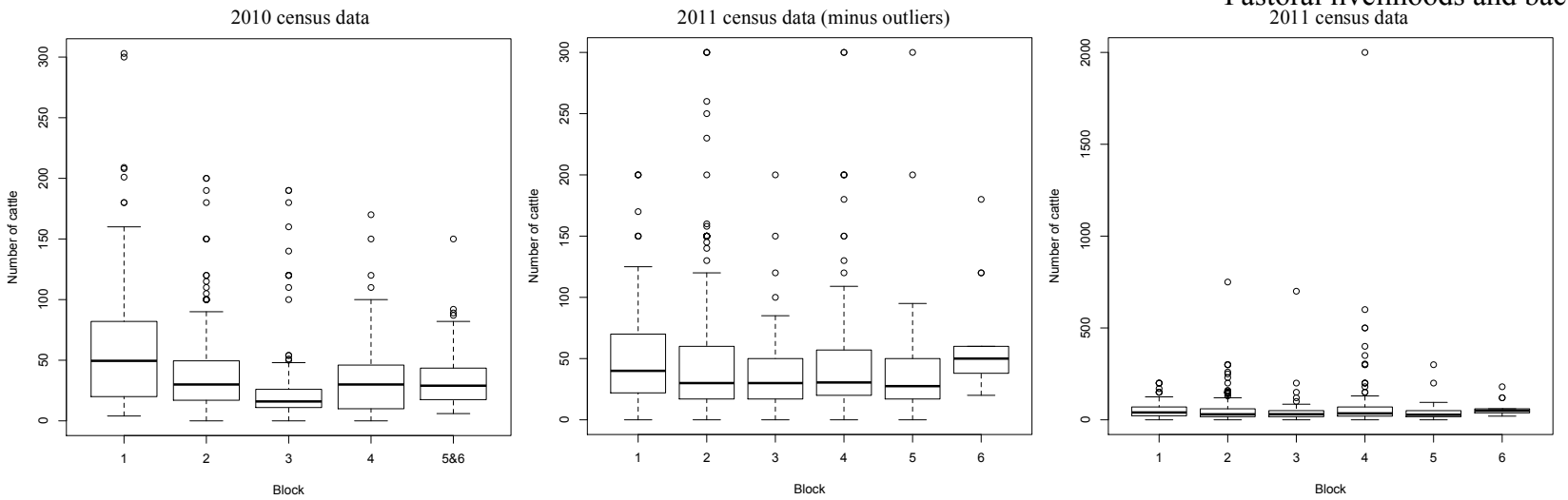


Figure 26 Number of cattle per household for each block, as given by 2010 census (left) and 2011 census for herds of 300 or less cattle (middle) and all herds (right)

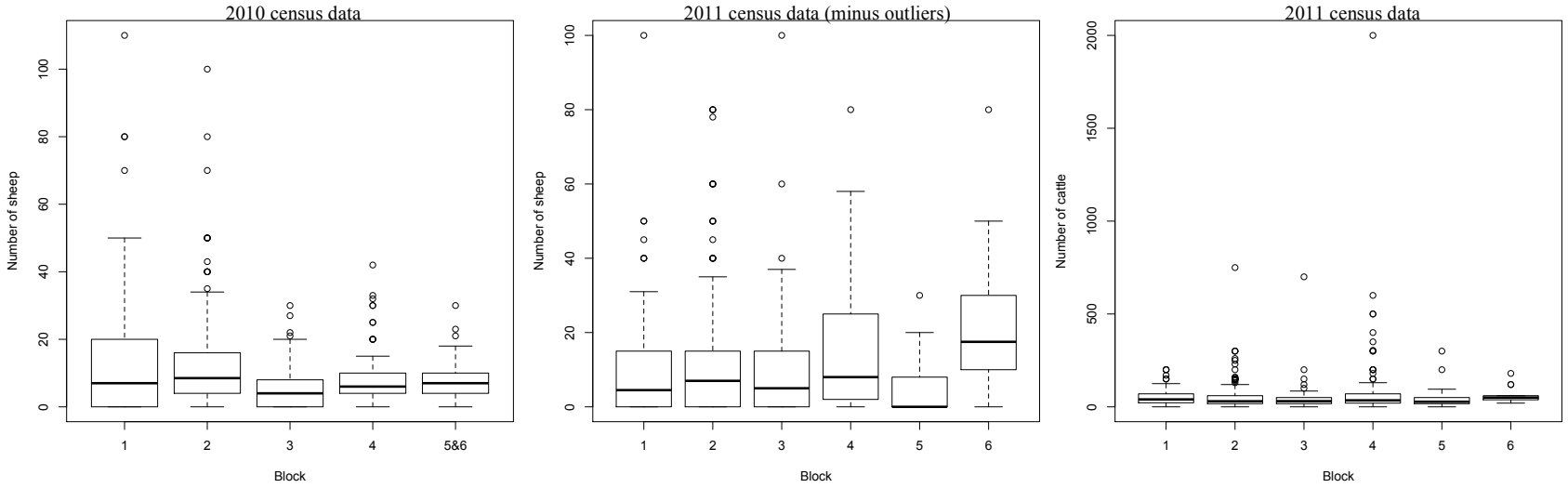


Figure 27 Number of sheep owned per household, as given by 2010 census (left) and 2011 census for flocks of 100 or less (middle) and all flocks (right)

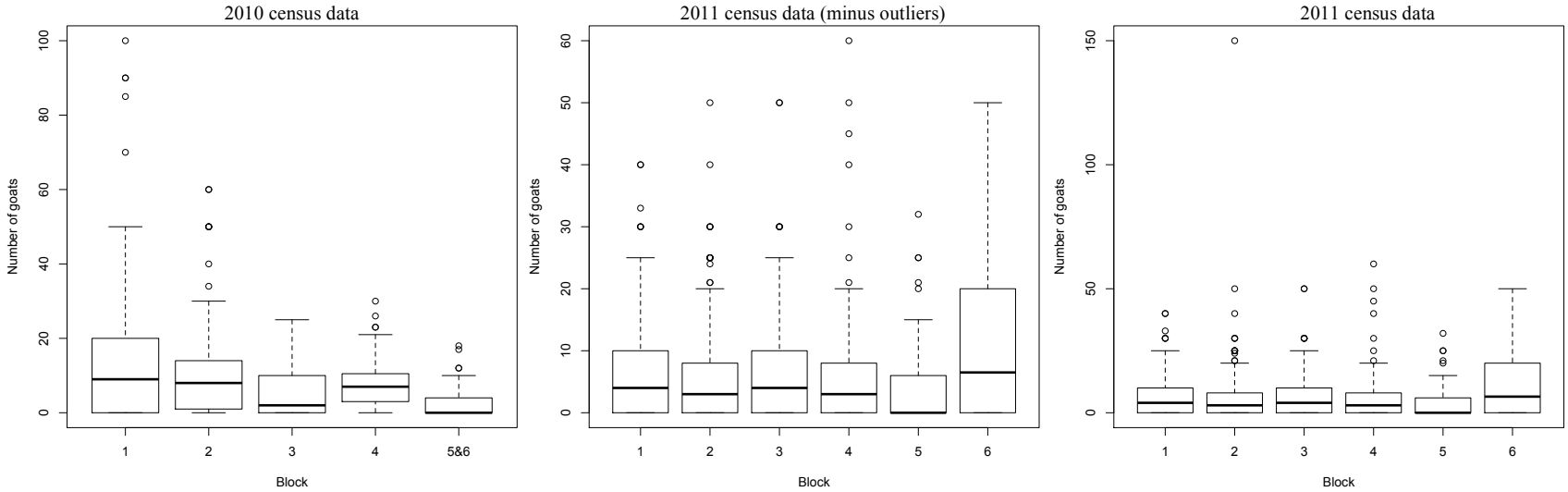


Figure 28 Number of goats owned per household for each block, as given by 2010 census (left) and 2011 census for herds of 60 or less (middle) and all herds (right)

3.2.3.6.2 Regression analysis

A least squares regression line was fitted to the scatterplot of household size versus herd size (Figure 29) to examine the relationship between the response variable (herd size) and predictor variable (household size). Three model orders were investigated for the regression fit, including a linear, quadratic and cubic model. The quadratic and cubic models can better account for the curvilinear pattern in the data.

Regression analysis gives the following regression equation for the increase in number of cattle at household level depending household size:

Cattle = 16.1 + 3.36 People

For each increase in household size by one person, the cattle herd size is expected to increase by 3.36 cattle (coefficient 3.36).

The regression results reveal that household size as a predictor of cattle herd size is significant because of the low p-value obtained (p=0.000). The household size predictor accounts for 7.5% of the variance of herd size (R-Sq = 7.5%).

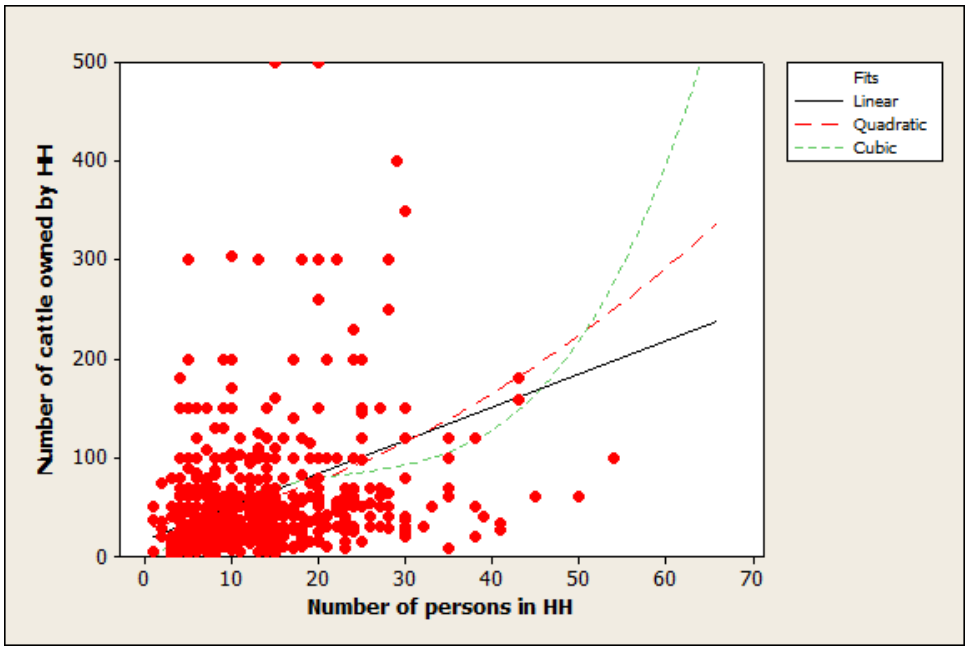


Figure 29 Scatterplot of household size versus cattle herd size with regression line determined using linear, quadratic and cubic models (data points for herd size >500 cattle not included)

3.2.3.7 Livestock ownership and time since settled in KGR

Scatterplots and boxplots of number of years a household has been settled in KGR versus number of cattle, sheep and goats per household are presented in Figure 30, Figure 31 and Figure 32 respectively.

The boxplot of Figure 30 shows that the median herd size fluctuates over time since settlement in KGR. Outliers seem to increase in frequency and magnitude as the year households moved to KGR augments (more recent move to KGR). This is especially apparent for households that moved into KGR in 2010 and 2011 (the new immigrants) as many of those households have herds of 100 or more cattle.

The scatterplot of Figure 30 shows that the few households that settled in the KGR between 1978 and 1990 have herd sizes of 100-150 cattle maximum. This ceiling increases to 200 for households moving in between 1991-2000 and to 200-250 cattle for households moving to KGR between 2001-2009. The new-immigrant households moving to KGR in 2010-2011 have numerous outlier households with very large herd sizes of 500-700 cattle. The linear regression line fit on the scatterplot shows a weak positive linear relationship whilst the quadratic and cubic model describes a U shaped curvature in the data. Pearson's and Spearman's rank correlation coefficients for year of settlement in KGR and cattle herd size are 0.188 and 0.191 respectively.

Figure 31 shows the median sheep flock size fluctuates over time spent in KGR. New immigrant households show a higher frequency and magnitude of outliers. The linear regression fit is positive but weaker than for cattle. A u-shaped quadratic curve and undulating cubic fit are also observed. Pearson's and Spearman's rank correlation coefficients for year of settlement in KGR sheep flock 0.087 and 0.183 respectively.

Figure 32 shows the same fluctuation in goat herd size over time since settled in KGR but the new immigrant median goat herd size is lower than for households that have moved to KGR for a longer period. Indeed the Pearson's and Spearman's rank correlation coefficients for year of settlement in KGR goat herd size -0.080 and -0.127 respectively, showing that there is a very weak negative linear correlation between both variables.

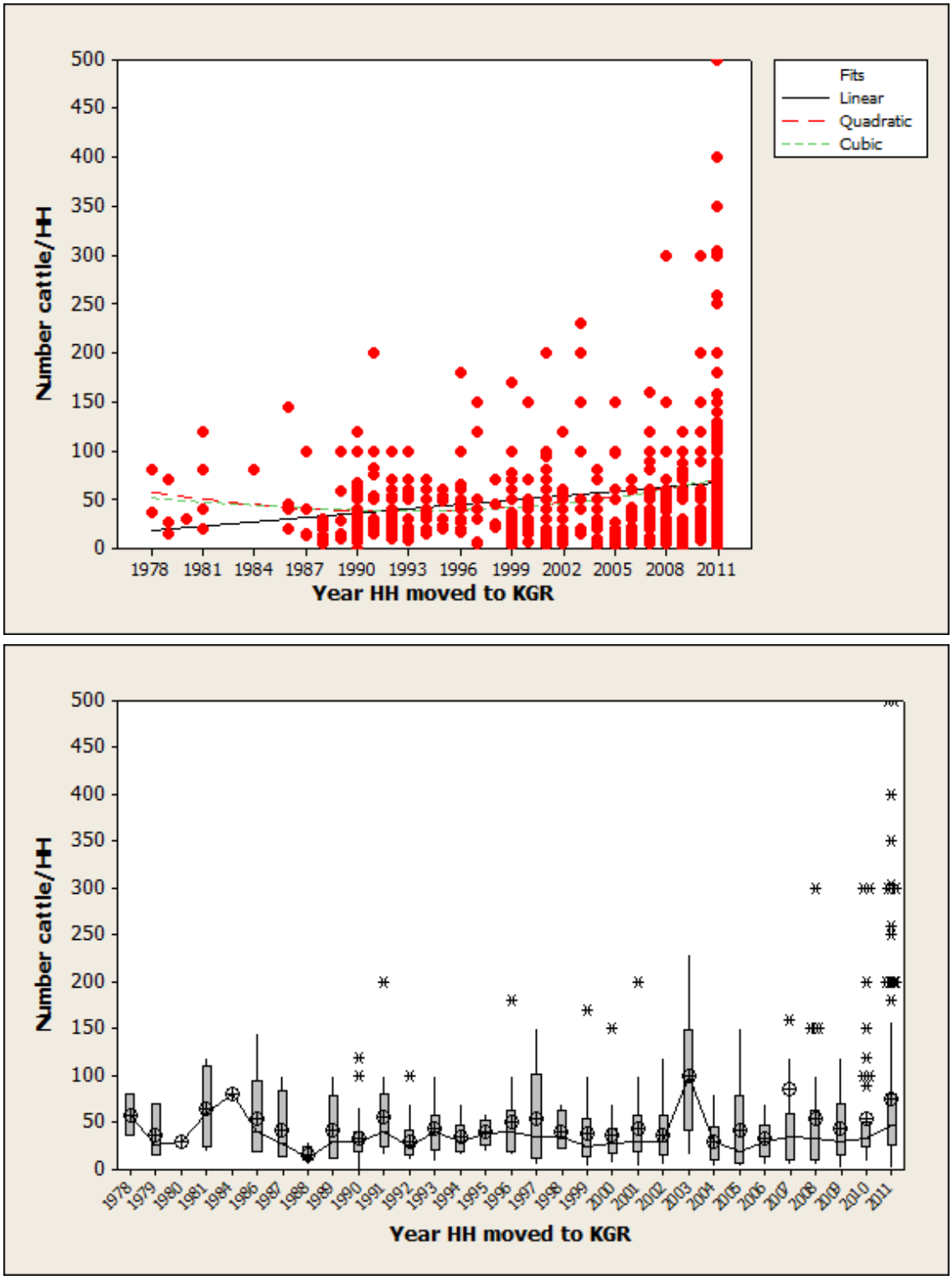


Figure 30 Scatterplot with regression line determined using linear, quadratic and linear models (top panel) and boxplot (bottom panel) of year household moved to KGR versus number of cattle per household (only households with herd size of 500 or less cattle plotted)

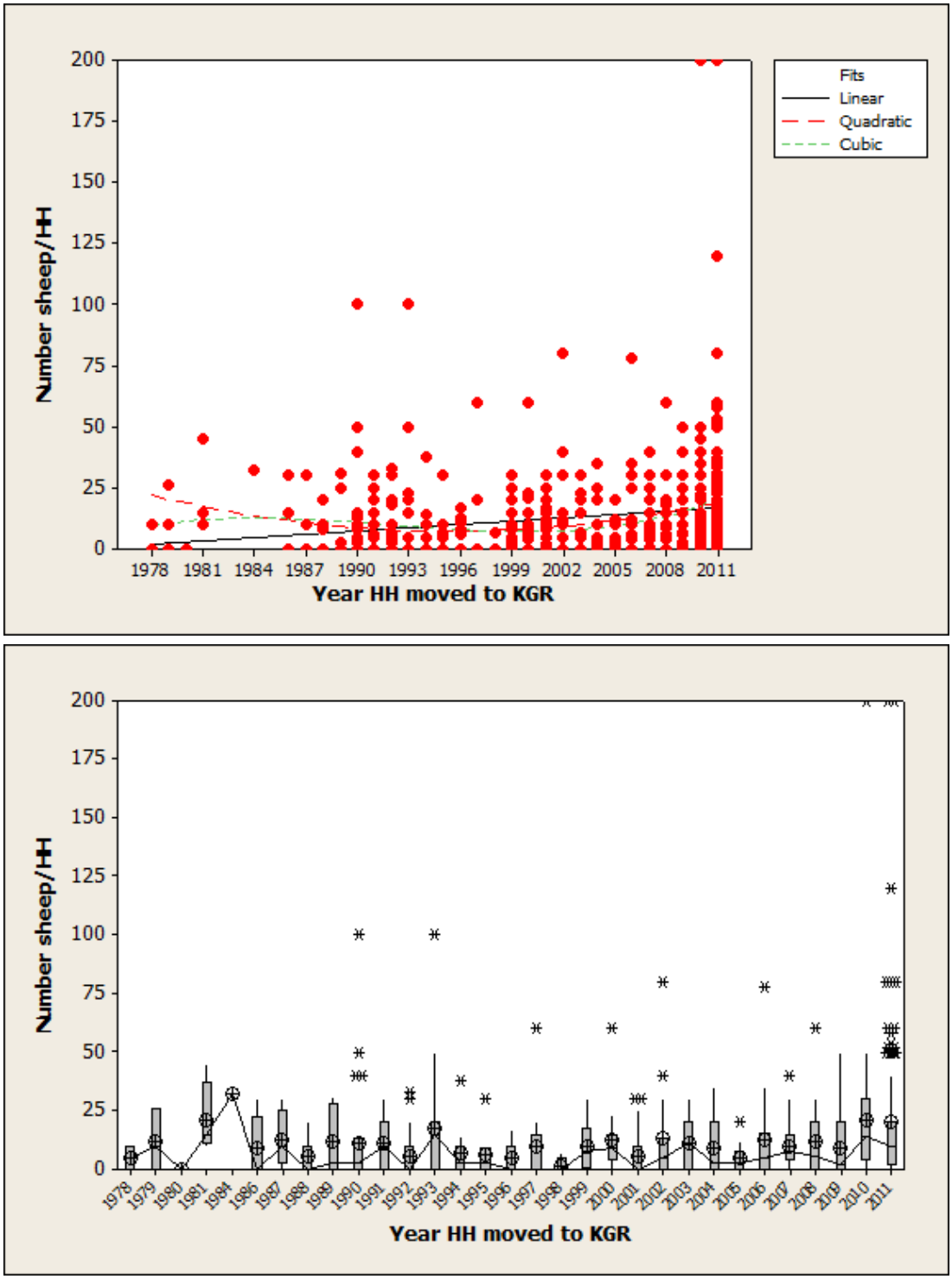


Figure 31 Scatterplot with regression line determined using linear, quadratic and linear models (top panel) and boxplot (bottom panel) of year household moved to KGR versus number of sheep per household (only households with flock size of 200 or less sheep plotted)

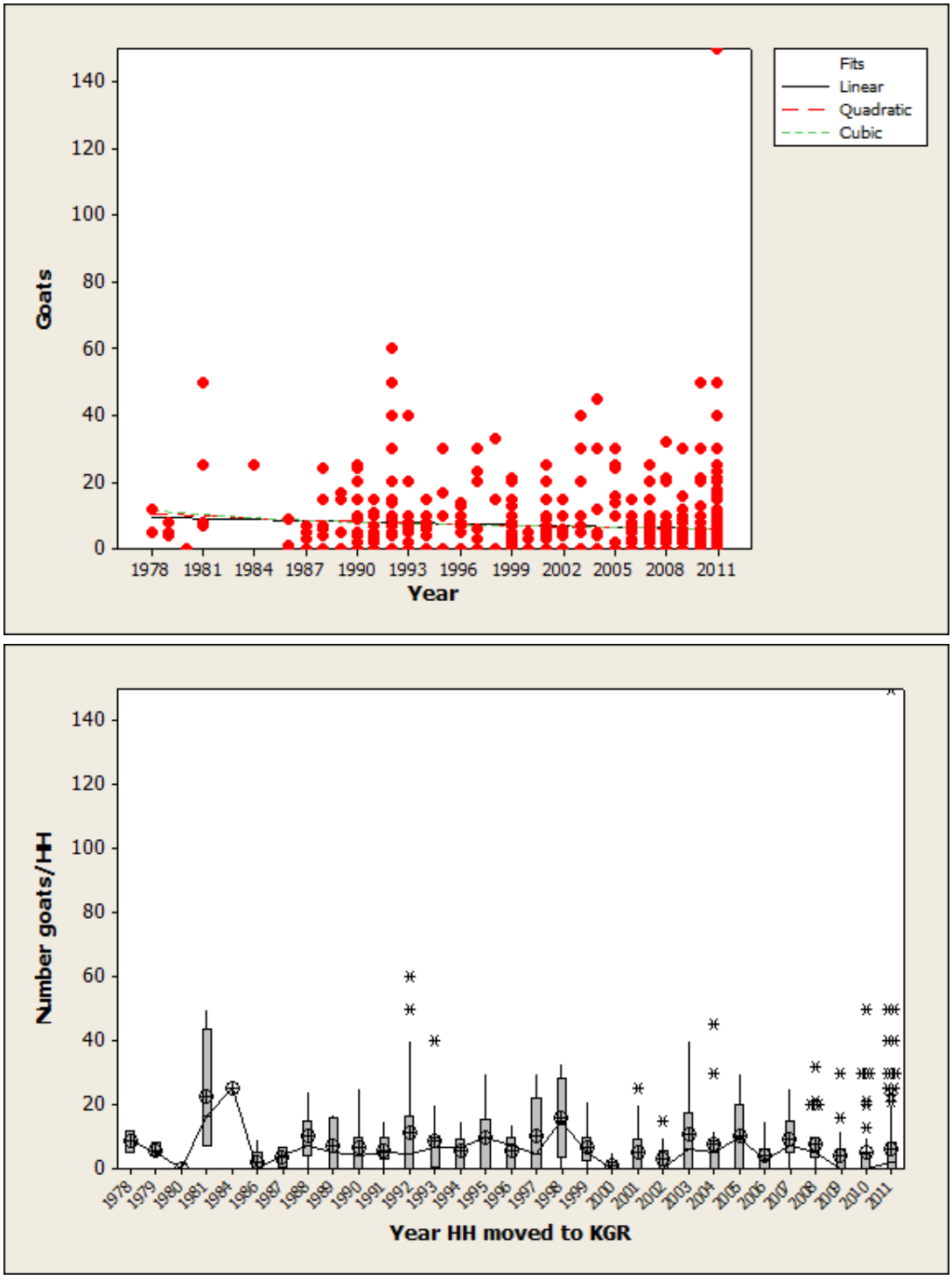


Figure 32 Scatterplot with regression line determined using linear, quadratic and linear models (top panel) and boxplot (bottom panel) of year household moved to KGR versus number of goats per household (only households with herd size of 150 or less goats plotted)

To further compare cattle, sheep and goat ownership between new immigrant households (that moved into KGR in 2010 and 2011) and those that settled in KGR prior to 2010, boxplots have been plotted (Figure 33). The boxplots summarise data for 'all households except the new immigrants', both from the 2010 census (households which moved between 1979 and 2009), and 2011 census (households which moved between 1978 and 2009). This can then be compared with values for households that moved to KGR in 2010 and 2011. The difference between the 1978 and 1979 lower range is because the oldest household in the KGR according to the 2010 census settled in 1979 whereas for the 2011 census this was recorded as 1978.

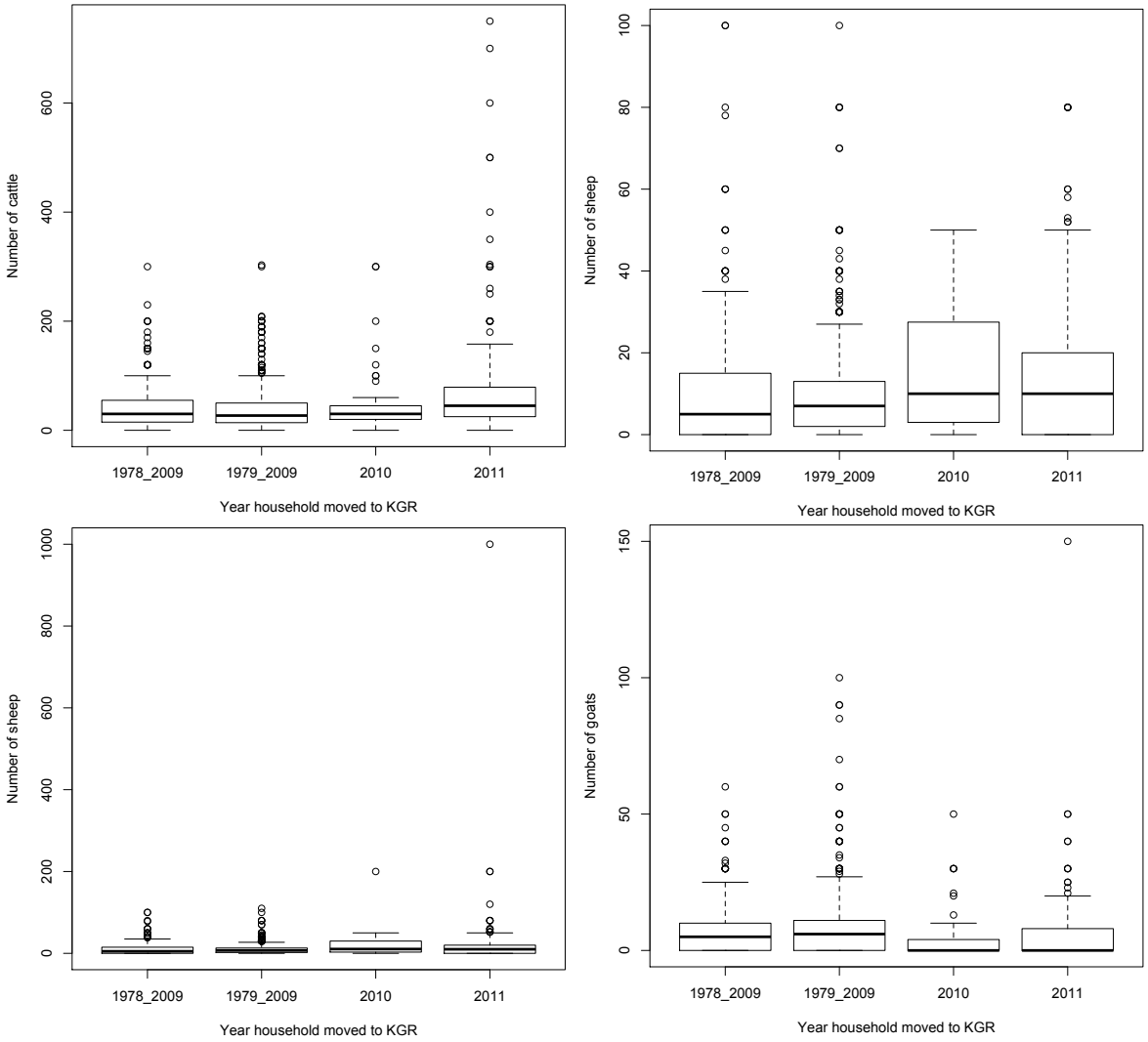


Figure 33 Household ownership of cattle (top left), sheep (for flocks of 100 or less, top right; all sheep flocks, bottom left) and goats (bottom right) during different time periods

The boxplot for cattle shows the 2010 immigrants have a similar median to that of 1978-1990 households. 2011 immigrants, however, have a slightly higher median number of cattle per household and a greater number of households with over 300 cattle (Figure 33). For sheep, both 2010 and 2011 immigrants have a slightly higher median of sheep per household, and like for cattle, 2011 households have more outliers. The inverse is observed for goats, with 2010 and 2011 immigrants having a lower median of goats per household.

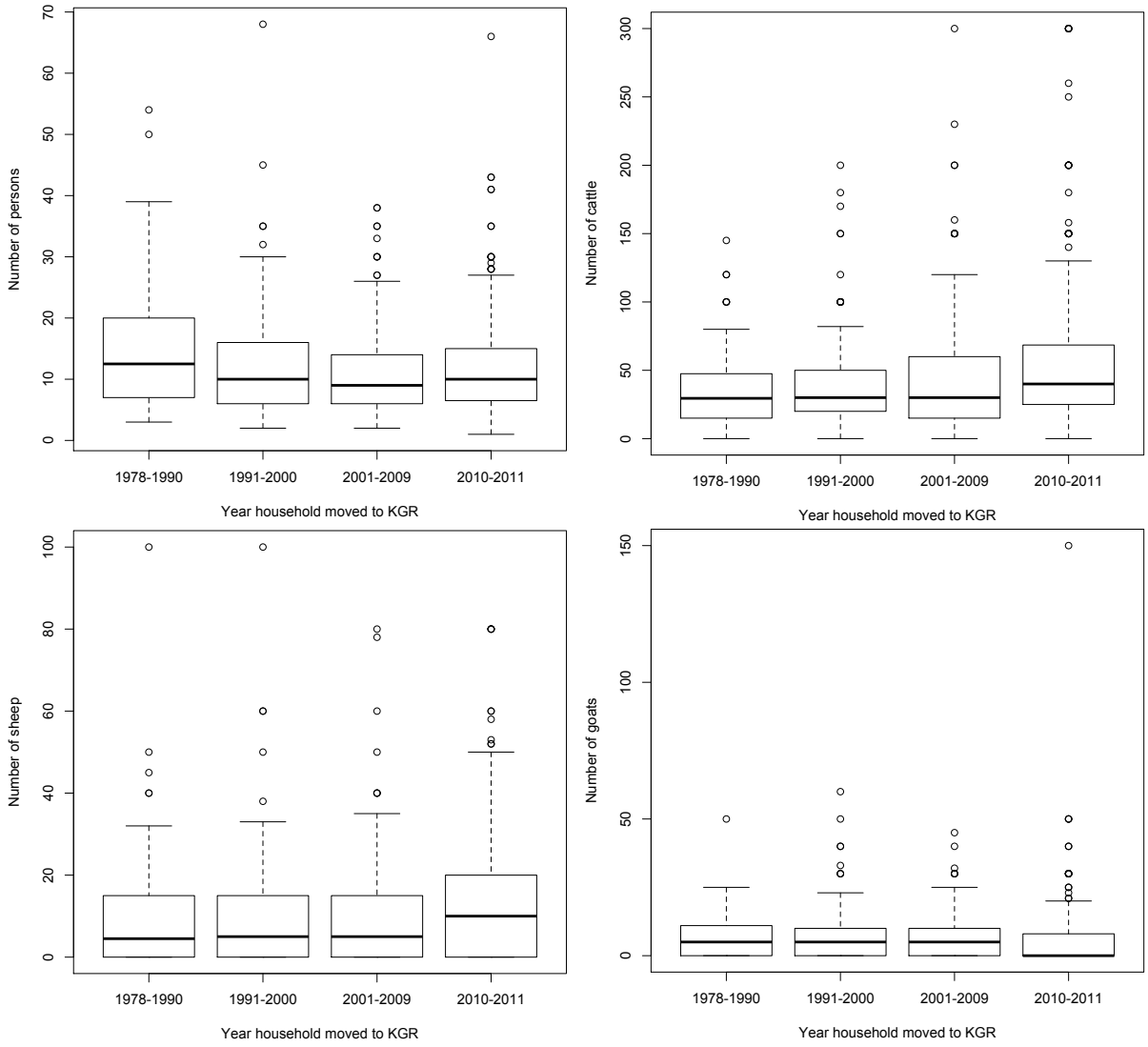


Figure 34 Number of persons (top left), cattle (top right, sheep (bottom left) and goats (bottom right), 2011 census

To complement the data presented in Figure 30, Figure 31 and Figure 32 additional boxplots were prepared for the 2011 census data grouping households that moved to

KGR 1978 - 1990, 1991 - 2000, 2001 -2009 and 2010 - 2011. The median number of people per household was found to be highest for the pre-1990s households with little difference between medians for other households (Figure 34). The median and upper quartile number for cattle and sheep per household was highest for new immigrants, with all other households having roughly similar medians (Figure 34).

The medians for the four categories (1978-1990, 1991-2000, 2001-2009 and 2010-2011) are similar. However, the boxplots show a tendency for some higher cattle herd and sheep flock size over time. For goats the reverse was observed, new immigrants having lower median than other households (Figure 34).

3.2.3.8 Origin of households

The location of origin of the first settlers who moved into KGR between 1974 and 1989 is shown in Figure 35. Thirty-two households living in KGR during the 2011 census were recorded as having settled during this period. Most households were from areas surrounding or adjacent to KGR: Zangon-Kataf LGA (8); Zonkwa (7); and Abet (2). Zonkwa is the main town in the Zangon-Kataf LGA. Six households originated from the fadama areas to the south, three from Lafiya in Nassarawa State, and three from Makurdi and Benue in Benue State. To the west of KGR, one household originated from Saminaka (Niger State). To the east, one household came from Bauchi and one from Jos.

A total of 74 households moved to KGR between 1990-1993 (Figure 35). Of those, 53 originated from within the vicinity of KGR. Nineteen households came from Kafanchan, 13 from Kachia, 13 from Zangon-Kataf LGA, and the remainder from Lere, Birnin Gwari, Kagoro, Katul, Madakiya and Zonkwa. To the south of KGR, 4 households came from Nassarawa State (Lafiya, Nassarawa and Gidan Magoro), 3 households from Benue State (Makurdi, Benue and Zanko). To the east, only one household originated from Bauchi, and 4 households came from Jos. To the west, five households came from Saminaka, Niger State. Four households came from north of KGR, near Kano.

Of the 38 households that moved to KGR between 1994 and 1998, 34 came from close to KGR, within Kaduna State. Of the remaining 4 households, 2 came from the south (Nassarawa State) and 2 from the west (Niger State) (Figure 35).

In all 77 households moved to KGR between 1999-2003, 31 of which were from Kaduna State (close to KGR) (Figure 35). To the south, four households were from Nassarawa State and 3 from Benue State. To the east, only one household was from Bauchi. To the southeast four households were from Plateau State, and to the west five households were from Niger State.

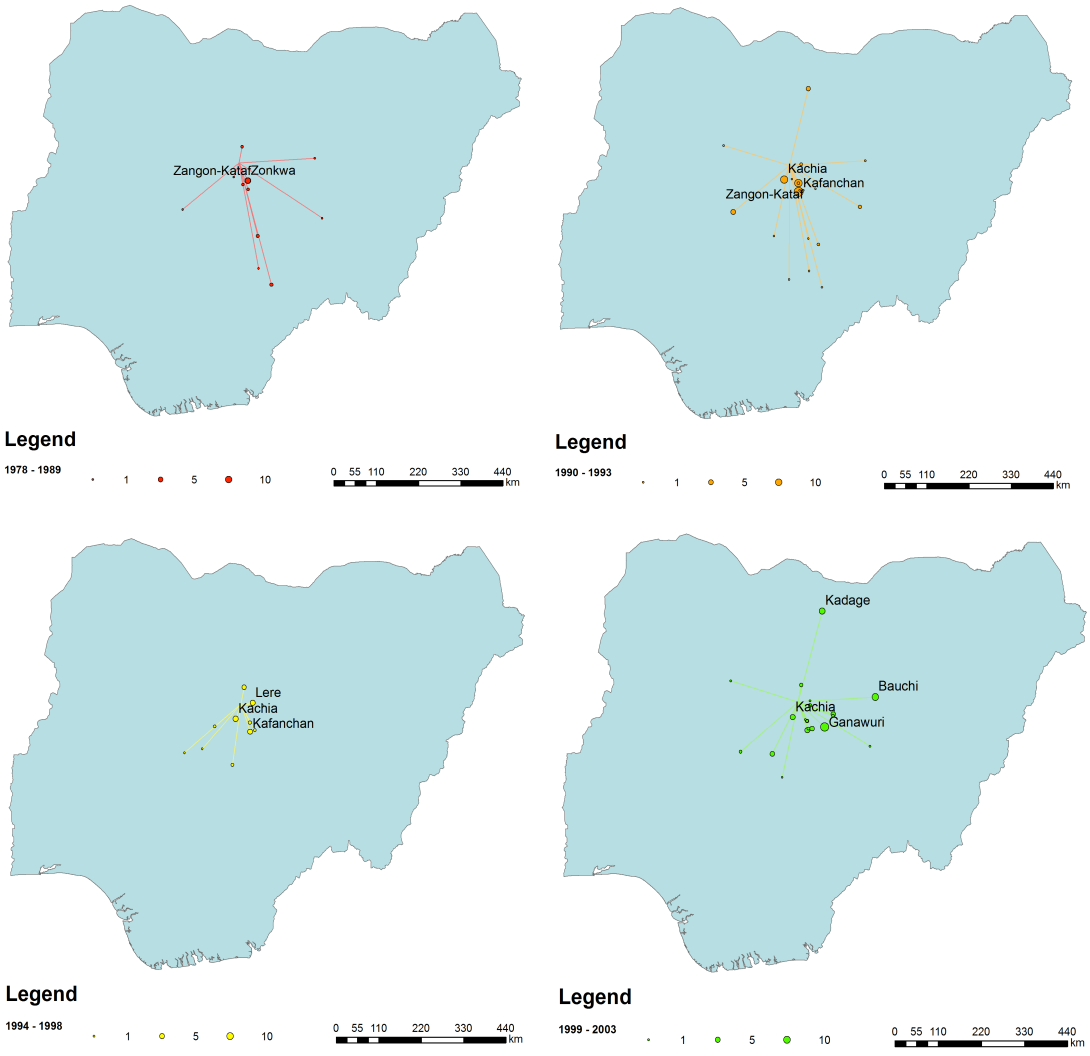


Figure 35 Location of origin of HH that moved to KGR between 1978-189 (top left), 1990-1993 (top right), 1994-1998 (bottom left) and 1999-2003 (bottom right) (size of dot proportional to number of households, map prepared by Ward Bryssinckx)

Between 2004 and 2006, 49 households moved into KGR. Thirty-four came from Kaduna State. One came from Nassarawa State in the south, 1 from Plateau State in the southeast, 1 from Bauchi in the east and 8 from Saminaka in Niger State (west) (Figure 36).

Between 2007 and 2010, 126 households moved into KGR of which 83 were from Kaduna State. One household originated from the east in Bauchi, 3 households from Plateau state in the southeast and one household from the far southeast, Jalingo in Taraba State. One household was from Okoja, Kogi State, to the southwest of KGR. 34 households were from near Saminaka in Niger State, and 1 household from the North, near Kano (Figure 36).

For the new 2011 immigrants, of the 193 households that moved in to KGR, 164 were from Kaduna State, 25 were from Plateau State, and three were from Katsina State in the North and one from Niger State (Figure 36).

The bottom left panel of Figure 36 is a compilation of the first 7 maps. The map illustrates that most households that have moved to KGR are from Kaduna State, and from areas nearby KGR. Households have come from multiple states, however, some from fadama areas to the south, some from Niger State in the West, some from Bauchi State to the east and Plateau State in the southeast, and some from as far north as Kano and Katsina. All households have come from areas within a 400km radius of KGR, and none have come from the very far southwest, southeast, northwest or northeast corners of Nigeria.

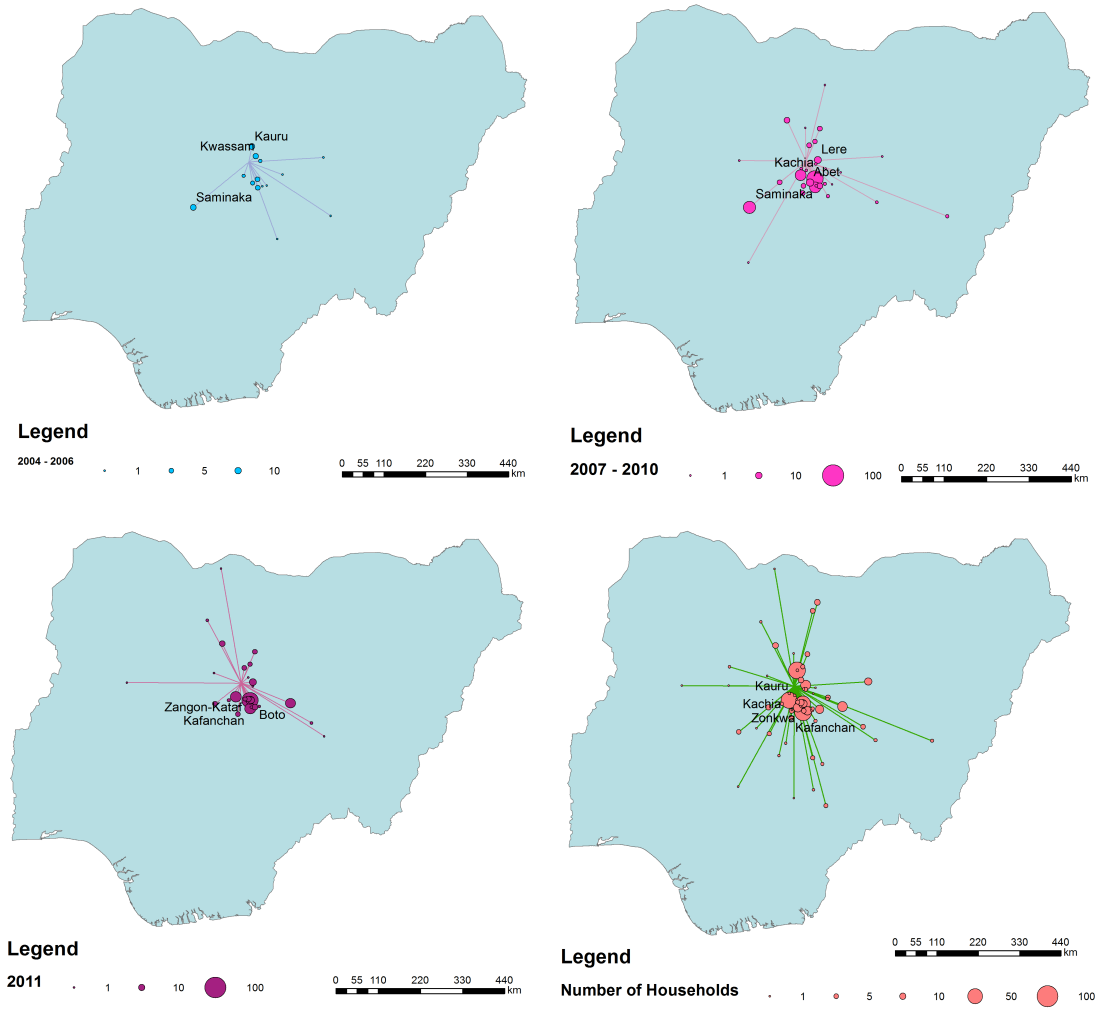


Figure 36 Location of origin of households that moved to KGR between 2004-2006 (top left), 2007-2010 (top right), 2011 (bottom left) and 1978- 2011 (bottom right) (size of dot proportional to number of households, map prepared by Ward Bryssinckx)

3.2.3.9 Transhumance behaviour in KGR

To assess the transhumance practice of the KGR community, households were asked if they took any of their cattle out of the KGR during the wet or dry season.

The percentage of households practicing transhumance out of KGR for households that settled in KGR during different time periods goes from 23.8% for the older settlers of 1978-1990, to 28.5% for the 1991-2000 settlers, 30.7% for the 2001-2009 settlers and 30.6% for the 2010 settlers (Figure 37). This would suggest that migration out of KGR decreases as the length of time a household has settled in KGR

increases. As previously explained, migration data for 2011 households is supposed to reflect migratory habits prior to their move to KGR.

The low percentage (22%) of transhumant households has to be interpreted with care. Some census interviewers questioned households on their movements out of KGR, but did not modify this question to migration from place of origin for 2011 households. Information on transhumant behaviour prior to moving to KGR for 2011 may not have been captured (they would not have had time to move out having moved in 2 months previously).

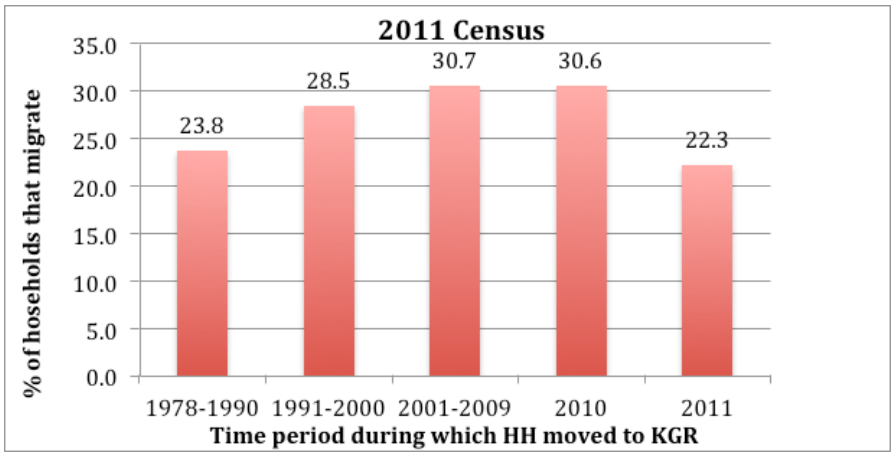


Figure 37 Percentage of transhumant households

3.2.3.10 FGDs and KIIs

3.2.3.10.1 What are the major events that have impacted on the KGR community in the last 40 years?

The District Head avisor and long-term KGR residents described a large World Bank project the ILCA Sub-humid Zone Programme in the 1980s (see 3.1.4.2.4). Since then the most notable event has been the mass immigration of May 2011.

3.2.3.10.2 Why do people move to KGR and where do they come from?

The unanimous answer was "*to get away from conflict situations in other areas*". The KGR is seen as a safe haven and a legitimate area of land set aside for Fulani by the government, by-passing the land rights issues which Fulani are confronted with in zones shared with crop farmers. People were reported to have emigrated from numerous locations: mostly from 50 km southeast of KGR (Kafanchan, Zonkwa and

Zango-Kataf), from the east and southeast (Lere, Ganawuri and Boto), from 300km southwest (Saminaka) or from the north (Kauru) (see Figure 35 and Figure 36 for location). The reason for moving to these areas was confirmed to be because of outbreaks of violence. A large number of households which settled in KGR was the reserve was first established were reported to have come from close by and within the Kachia LGA. All KIIs and FGDs emphasised that once people move in to the KGR they very rarely move out, because, as one man stated: *"we are at peace here"*.

3.2.3.10.3 Why do households settle in specific blocks/villages/areas? Who decides who settles there?

The District Head advisor confirmed that when KGR first opened the Project Officer was in charge of issuing permits and allocating land to all families wishing to settle within the KGR. With the gradual dissolution of the Project Office the community now use their own governance system to decide who settles where. Each family must report to the District Head and if they have relatives within the KGR they must then go and consult with the Village Head of the village of residence of family members. If there is space then the family will be allowed to settle in the same village as their relatives. Generally Fulani prefer to live nearby kinship members of the same clan.

Most people want to settle close to the central market area of Tampol and close to the main road that subdivides Block 1 from Block 2. People first moved into these blocks because there was water access (reservoirs) and schools. The land from these two blocks was gradually cleared making it easier to farm. As Block 1 and Block 2 became crowded, people settled in Block 3, Block 4 and eventually Block 5 and 6.

With the mass immigration of May 2011, there was no time to deliberate over where people should settle, so they just set up camp as where there was space as close to the central amenities as possible for convenience. Hence most new immigrant families settled in Block 2, 3 and 4. Blocks 5 and 6 were too far away and remote to be appealing and inaccessible at the start of the wet season due to poor road conditions, and Block 1 was already overcrowded.

3.2.3.10.4 Are there differences between the HH of different blocks? What are these differences and why do they matter?

The blocks are made up of different villages. Each village has a village head and he generally heads the wealthiest household of that village. In a single village there are generally multiple households belonging to the same clan. Clan membership influences the livelihood strategy (pastoralism versus agro-pastoralism) to some degree: the Yabaji for example have held on their traditional Bororo roots and pastoralist heritage. In general, it is this similitude in clan membership at village level and contrast between the clans of different villages, which accounts for the differences in household demographics observed across the blocks.

There is only one village in Block 1 (Nassawara). In general the households inhabiting this block moved to KGR first and are regarded as the wealthy community elite. They have larger cattle herds and farm more land and are more 'settled'. Families have square houses made of cement or mud with corrugated iron roofs.

Block 2 is more diverse in nature since it is made up of 4 villages. The two villages (Wuro Nyako and Wuro Fulbe) along the main road in and out of the reserve are considered to be wealthy and are considered to be inhabited by longer–time settlers by the KGR community. Wuro Fulbe has the most 'urban' character within KGR being situated adjacent to the market area of Tampol. This is also the village where the District Head lives. To the east of Tampol there is a main road going down towards the River Kaduna, which runs along most eastern edge of Block 2. There are two villages along this road; Margire and further down the road, Wuro Fulbe. Inhabitants of these two villages are poorer, with smaller herd sizes and inhabitants are more isolated from the rest of the reserve.

Block 3 is made up of the villages of Wuro Saleh and Mayo Borno. Both villages are regarded as containing households that have smaller herds than those of Block 1 and the wealthier households of Block 2.

Block 4 is made up of only one village, Tilde Bayero, located on the highest terrain of KGR. Block 4 is heavily forested with limited land cleared for farming. Homesteads are made of less permanent structures made from branches and leaves. Herd sizes of households in this block are reported as being higher than in Block 3.

Block 5 is made up of one village, Wuro Modi. More land is cleared for crop farming than for Block 4, and households are regarded as wealthy in livestock assets.

Block 6 is made up of one village, Giyja. Households in this block are reported to have very large herds since the inhabitants are considered mostly 'pure' or traditional pastoralists. The reason these households choose to settle in this remote block with very poor road access is because this block is adjacent to a transhumance corridor permitting easy access of herds in and out of the KGR for grazing and transhumance.

3.2.3.10.5 Are there any differences between the new immigrant HH and those that have been settled in KGR for longer?

The FGDs and KIIs were in agreement over the fact that a large number of immigrant families brought with them very large cattle herds, larger than those generally kept by settled households. The reason for settled households having smaller herds was that the carrying capacity and grazing resources in KGR are limited. If they have large herds they tend to split them into multiple sub-herds, some of which are kept on holdings outside of the KGR by relatives (see Chapter 4).

3.2.4 Discussion

3.2.4.1 Conflict and immigration

The census data shows four main periods of immigration into the KGR. The first immigration peak was in 1990-1993, during which 96 households moved in. In 1999-2003, 105 households moved to the KGR. In 2007-2010, 173 households moved into the reserve and in 2011 saw a mass immigration of 249 households.

Data only captures the number of households that moved in to the KGR at a particular time point and have since stayed so it is possible that the overall number of households which moved in at those defined time-points was higher, but that some of those households have since left the KGR and returned to their areas of origin or moved on to another location. This limitation only applies to the first three time periods (not to the 2011 households, as the 2011 census was conducted shortly after this mass immigration event). However, a key informant interview (KII) undertaken with a prominent community member who had lived through all four immigration periods confirmed that households who move into the KGR rarely move out. The

reluctance of pastoralists to relocate was also described by Gefu (1992), who concluded that in general, settled pastoralists do not like to move. This would suggest, therefore, that the number of households coming in to the KGR and establishing permanent residence has been increasing over time.

The author verified the motivation for settling in KGR directly with the respondents of new immigrant households during the census as well as during FGDs and KIIs: post-election violence in the areas of Zango-Kataf, Kafanchana and Boto (Kaduna State) was the main driver for fleeing (Figure 36).

The 2011 crisis was marked by civil unrest and violent protests in the northern states of Kano, Kaduna, Bauchi, Gombe, Niger and Borno, both before and after the April presidential election. The Nigerian Red Cross estimated that 75,000, 452 and 288 people were displaced, injured and killed respectively and that property worth hundreds of thousands of USD had been destroyed (IFRC, 2011). During this crisis, Fulani herdsmen were singled out in the press as responsible for some incidents – accusations were never proven but fuelled unease and fear among the Fulani. Alongside this is a long-term resentment developed among some minority ethnic groups at the Hausa-Fulani domination of public life in northern Nigeria and their role in national politics (Shaw, A., pers. comm,).

The drivers for the settling of households in 1990 - 1993, 1999 - 2003 and 2007-2010, while less certain, were confirmed during focus group discussions with community members, and the dates of peak immigration also coincide with the most notable periods of rioting in Northern Nigeria between 1990 and 2010 (Tasneem, 2014). The Maitatsine riots of the early 1980s left nearly 10,000 people dead. These were mainly confined to towns (initially Kano, later Gombe, Kaduna Yola and Bulumkuttu, near Maiduguri), to which the followers of the Islamic religious extremist fled after his death.

The first period of immigration 1990 – 1993 was marked by the violence in Bauchi in 1991 and in Zango-Kataf in 1992. Riots in Bauchi State were triggered by a minor incident at a small-town abattoir close to the State capital. A Christian butcher was reported attacked by a Muslim customer leading to a riot and numerous deaths. The violence quickly spread to other parts of the state, where Christians and Muslims

attacked one another and homes were looted, vandalised and set on fire. The incident was estimated to have killed and injured numerous people and displaced 5000 (Falola, 1998). In May 1992 violence erupted in Zangon-Kataf as a result of a Muslim/Hausa versus Christian/Kataf conflict. Everything of value was said to have been destroyed in the area where rioting occurred (Falola, 1998). Most households (54%) that immigrated to the KGR during this period were from Kafanchan, Zangon-Kataf and Zonkwa. These three towns are in the same general area. Immigration during this period is likely due to the Zangon-Kataf crisis rather than the Bauchi riots, even though one household reported having come from Bauchi (Figure 35).

The early 2000s were marked by three crises of note: the 2000 crisis of Kaduna, the Jos riots of 2001 and the 2002 Kaduna 'Miss World Riots'. Fighting between Muslims and Christians in Kaduna in February-March 2000 followed a debate around the proposed introduction of Sharia in Kaduna State and resulted in the death of 2000 persons. A further 250 people were killed in November 2002 when protests relating to the Miss World beauty contest due to be held in Nigeria degenerated into riots and widespread violence ((HRW, 2003). The first Jos riot occurred in 2001 over the appointment of a Muslim politician, and resulted in the death of 1000 people, destruction of infrastructure and homes and the displacement of 200 civilians. In 2008, a riot broke out in Jos over local elections and mounting tension between Muslim and Christian gangs left 300 persons dead and 10,000 were displaced.

Only five households emigrating between 1999-2003 come from Jos and none came from Kaduna. Rather, a third of households (35) reported having moved from Ganawuri and Zangon-Kataf southwest of KGR (Figure 35). The Jos and Kaduna crisis were not drivers, therefore, for immigration into KGR. More localised conflict and tension in the Zangon-Kataf area was confirmed to be the main driver for people leaving this area, as confirmed through FGDs.

Households that moved into KGR between 2007 and 2010 were not from Jos. The majority (20%) came from 300km southwest (Saminaka), some (23%) from the north (Kauru), and others from nearby Kachia (7%) (Figure 36). Violence and tensions in these areas was again confirmed to push people out of these areas.

3.2.4.2 Characterising the differences between the blocks

The six blocks of KGR are distinct in size, proximity to the main market and trading area, vegetation density and cleared land for crop farming, road provision, proximity to dams or rivers, clinics, schools etc. Subtle differences between the blocks can help interpretation of trends in socioeconomic and epidemiological data. KGR households are diverse and diversity has increased with the 2011 influx of immigrants. The following observations are based on analysis of census data related to the knowledge accumulated through participatory methods (focus group discussions, key informant interviews and general observations). Division of KGR into blocks is administrative, but the KGR community regard these blocks as separate and distinct entities, referring to themselves as 'inhabitants of Block 1' or inhabitants of Block 2' etc. The characteristics of the six blocks are discussed here below.

3.2.4.2.1 Block 1

What distinguishes Block 1 from the other blocks is its prime location next to the main road into and out of KGR, proximity of market, health and schooling amenities and relatively large stretches of cleared woodland for crop farming. Block 1 has experienced a steady increase in population size and has been less affected by mass migration than the other blocks. Block 1 has the highest percentage of households with more than 3 wives (Figure 21), a higher median and interquartile range (IQR) of persons per household (Figure 24), higher median and IQR of cattle per household (Figure 26) higher median and IQR of sheep (for 2010 census data but not 2011 data) (Figure 27), and a higher median and IQR of goats (Figure 28).

Block 1 has a high percentage of 'first settlers' who moved in when the KGR was first established: 18 (28.1%) of the households that moved in to KGR between 1978 and 1990 are settled in Block 1. Most community leaders are based in Block 1, and influence decisions that affect the whole of KGR. When new migrants wish to settle in KGR, they are redirected to other blocks despite the prime location of this area, as inhabitants of Block 1 have the supremacy to avoid overcrowding of this block.

Large areas of this block have been cleared for crop farming indicating that households also engage in crop farming. The Fulani of KGR are agro-pastoralist but

the contribution of crop farming to the overall household economy will vary for individual households and across blocks. Households in Block 1 have large cropping areas, people have lived in Block 1 for longer and have therefore cleared more of the forest to make way for agriculture. Diversification of pastoralist livelihoods and relative contribution of crop farming to household economy is analysed in Chapter 4.

3.2.4.2.2 Blocks 2 and 4

Block 2 is the most populated block. It is close to the central market area, has good road access and has large areas of cleared land. The 'wealth' ranking of this block, based on number of households with three or more wives, number of cattle, sheep and goats owned per household is inferior to Block 1, but similar to Block 4 (in a more remote and vegetation dense location of the KGR, situated in a more elevated zone). KII and FGDs revealed Block 2 to be more diverse, comprising 4 villages (Block 1 is made up of a single village). Wealthier, elite and influential community leaders live opposite Block 1 and close to the central area of Tampol (central market area of KGR) and the poorer households live at the more remote and eastern end of the block. Figure 15 illustrates that two clusters of households exist in Block 2, one cluster is around Tampol (villages of Wuro Nyako and Wuro Fulbe) and the other cluster is close to the eastern boundary (villages Mayo Jamil and Margire).

3.2.4.2.3 Block 3

A similar number of households as in Blocks 1 and 4 are found in Block 3. The percentage number of household heads with 3 or more wives is higher for this block than that observed in Blocks 2 and 4, and the median number of cattle and sheep is lower. Crop farming may be proportionally more important than pastoralist activities for households in this block. A large proportion of Block 3 has been cleared for crop farming in contrast to Block 4, which was largely forested.

3.2.4.2.4 Blocks 5 and 6

Blocks 5 and 6 are the least populated blocks, situated the furthest away from the central market and amenities area (Tampol). The roads to these blocks are hazardous, especially during the rainy season. The two blocks have different characteristics. Whereas Block 5 has median cattle and sheep per household equal or lower than that

observed for Block 3, whereas Block 6 has the highest median of cattle and sheep (and goats) of any block in KGR for the 2011 census data. The top of the IQR is higher in Block 1 for the 2010 census data.

Households that have settled in Block 6 are relatively new immigrants, as no household settled in this Block before 2001 (Figure 18). FGDs and KIIs revealed that the households in Block 6 engage more in pastoralist than cropping activities, unlike inhabitants of Blocks 1, 2, 3, 4 and 5, who have an increasingly crop-based livelihood (see Chapter 4). Block 5 has the lowest average number of goats per household which fits with an area where cropping activities dominate (goats in KGR are more or less free range and if present would potentially devastate crops).

Blocks 1 and 6 (blocks with the highest median number of cattle per household) are located near the transhumance corridor at opposite north-south extremes of the KGR. Households are in a prime location to take their cattle out of KGR for grazing. This is advantageous for households with larger herds who would otherwise need to pass through cultivated areas of Blocks 2 to 5 to graze, and potentially damage crops.

3.2.4.3 Immigration into blocks over time

The post-election violence of April-May 2011 resulted in an increase in human, cattle and sheep populations of 75%. Figure 15, Figure 16 and Figure 20 show that the new immigrants moved into all blocks, with 37% into Block 2, 28% into Block 3, 23 % into Block 4, 9% into Block 1, 2.4% in to Block 6 and 0.8% in to Block 5. Hence most moved into Blocks 2, 3 and 4.

The settling pattern of households into different blocks is not random. Decision-making and governance go into the allocation of households into specific blocks during these periods of mass influx. Fulani communities are hierarchical, and the community elite ultimately decides where people can settle. It is officially the responsibility of the state government (Project Office) to oversee and regulate new settlement but this no longer occurs (KGR Project Officer, pers com.).

The Fulani have strong clan affiliation and new families moving in will most likely settle close to relatives of the same clan. If persons from the same area are displaced due to conflict, it is more likely that they will settle in the same block.

Different blocks have different sizes and characteristics, and as seen in the previous section, most people prefer to settle in the blocks closest to amenities (Blocks 1 and 2). The cumulative rise in number of households for Block 1 (Figure 18), shows that conflict-driven mass migration has not occurred in this block (unlike in other blocks), and that the increase in population has been more gradual. Block 1 is populated with some of the intellectual and ruling elite of KGR, who direct incoming households to other blocks to avoid over-population in Block 1. The first settlers of KGR were local people who had permanent or semi-permanent bases adjacent to the grazing reserve area (Oxby, 1984). This may have given them supremacy over households originating from further afield. One observation made by Oxby (1984) was that grazing reserve projects have invariably attracted the more settled herders.

In the early 1990s, when the population pressures within the KGR were less intense than today, more households were permitted to move to Block 1. At this stage the project office still oversaw the settling process. However, as the population of KGR grew, families were forced to settle in the more remote blocks, as seen by the influx of households to Blocks 5 and 6 during the mass immigration of the 2000s.

3.2.4.4 Differences in livestock ownership and HH size of new immigrants

To explore diversity in livestock ownership and HH size between new (2011) immigrants and all other households having moved into KGR in 2009 or earlier, the 2010 census data (HH that moved to KGR between 1979 - 2009) was compared to 2011 census data, treating 1978-2009, 2010 and 2011 households as separate groups.

The data suggest that the 2011 ‘new immigrant’ households have a much more dispersed and higher median cattle herd size, with numerous households (11) owning ‘mega-herds’ (over 300 animals in a herd) (Figure 20). FGDs revealed that when new households with very large herds move in, they eventually send some of their animals outside of KGR to be looked after by relatives. One explanation for the higher average cattle herd size of new immigrants may be that herd size does not only reflect wealth status, but also the extent to which a household undertakes cropping activities. Households with lower herd sizes undertake more cropping activities and may even sell some of their crops. Households with large herd sizes

may grow crops for subsistence but do not derive a source of cash income from this activity. Households settled in KGR are predominantly agro-pastoralist, and while there are very large herd sizes, the mean herd size (40.1 cattle per household), lower than that reported in the literature (Sutter, 1987, Pullan, 1979, Akpa et al., 2012). The relationship between crop farming and livestock ownership is explored in Chapter 4.

The pastoralists of KGR may be poorer than pastoralists living outside of grazing reserves, or they are substituting part of their pastoralism activities and livelihoods with crop farming. Returning to the comparison of new immigrants with households that have settled in KGR for a longer period, this would infer that new immigrants are either 'wealthier' than the KGR settlers, or that they have a more pastoral rather than crop orientated livelihood. The pattern with sheep flock size is similar to that of cattle (Figure 33), and one can infer that new immigrants are either wealthier or more pastoralism-oriented than the settled households of KGR, or that they have not yet had the opportunity to split up their herd into sub-herds and to send some of their animals to be reared on holdings outside of the KGR.

The reverse pattern is observed for goats (Figure 33), as more new immigrant households did not own any goats. In the previous section we discussed the fact that in KGR the crop-focused areas may potentially opt for fewer goats. If new immigrants have few goats, this may imply they intend to partake in crop farming. More likely is that the new immigrants are semi-nomadic or full nomadic pastoralists, for which goat keeping is not traditional. Goat keeping is associated with establishment of a permanent homestead (goats are not usually taken out grazing with cattle and sheep). This strengthens the premise that new immigrants are more 'traditional' pastoralist nomadic households. Another possibility is that the new immigrants owned goats prior to moving to the KGR but that these animals could not be brought to KGR as this species is not able or used to trek with cattle and sheep.

Livestock ownership of households that settled between 1978-1990 (hence who have lived in KGR the longest), those that settled 1991-2000, 2001-2009 and the new immigrants of 2010-2011 demonstrates that the median, IQR and whiskers of cattle herd size decrease as the period spent in KGR increases. The same is true for sheep

as sheep flock size also shows a very slight decrease as time spent in KGR increases. For goats, the inverse is observed (Figure 34).

The hypothesis that cattle herd size would reduce as the period since settlement in KGR increased was further explored. The scatterplot (Figure 30) of year during which household moved to KGR and herd size, and calculation of Pearson's and Spearman's rank correlation coefficients show that there is indeed a weak positive correlation (hence herd size would appear to reduce as period since settlement increases). The quadratic and cubic regression fit, however, show a u-shaped relationship: first settlers and new immigrants have the larger herd size and households in between lower herd size, hence the relationship between time spent in KGR and herd size may be more complex and there could be other factors at play. One important factor may be that the households that have been in KGR the longest, the community elite of Block 1 and Block 2, are more wealthy in terms of livestock assets. This was corroborated during FGDs: *"Our fellow herdsmen who have been here the longest were from wealthy clans and were able to maintain or to build up their herds better than those that came after"*.

The FGDs also revealed that herd size, therefore, is also related to clan membership. The first settlers into KGR were from the same clan. Different clans, much like families in western culture, have varying wealth status.

The boxplot of Figure 30 shows that the relationship between herd size and time spent in KGR is not so straightforward. The median and spread of data around that median fluctuates randomly over time. Households that settled in 2003, for example, have a much higher median herd size. Cross checking to the census data revealed that most households which moved into KGR in 2003 had the same origin and same family name, hence they belonged to the same clan. This again shows that clan membership is an important determinant of cattle wealth.

The increase in frequency and magnitude of outliers (large herds of more than 150 cattle), in part accounts for the linear positive correlation between herd size and time spent in KGR. The boxplot of Figure 30 shows that the new immigrants of 2011 have a large number of mega-herds, and the trend seems to be that the magnitude and frequency of these outlier herds reduces as the time spent in KGR increases.

Calculation of the Pearson and Spearman's rank correlation coefficient for excluding households with more than 150 cattle demonstrates a weaker positive linear correlation (Pearson's = 0.109 and Spearman's rank = 0.156) than if herds of 150 cattle or more are included (Pearson's = 0.118 and Spearman's rank=0.191).

The relationship between time since settlement in KGR and sheep flock size was similar to that observed with cattle herd size (Figure 31) but with weaker correlation. Correlation between year household moved to KGR and goad herd size was weakly negative (Figure 32), suggesting goat herd size increases with time spent in KGR. Goats are associated with settled sedentary behaviour and not taken on migration.

Changes associated with sedentarisation were explored by Jabbar et al. (1995), who found that herd owners who had settled for a shorter period had considerably larger herd sizes than those who had been in their present settlement for longer (the herd size decreased slowly up to about 10 years of settlement then dropped sharply). Herds that moved longer distances between seasons were much larger than the herd that did not move or moved short distances. Indicators for sedentarisation of households in the KGR are explored in the next section.

3.2.4.5 Correlation between cattle herd, sheep flock and goat herd size and household size

Herd size and household size co-vary, and the relationship is curvilinear (Figure 29). Households with more livestock wealth have more people (there is a positive and statistically significant correlation between household size and number of cattle owned by household). Once a household has approximately 150 cattle per household, any further increase in herd size does not lead to further increases in number of persons per household. The larger the number of cattle within a household the more people can derive nutrition (milk in this context) and income from these animals. A larger herd size requires a larger workforce to maintain it. The numbers of cattle and people at the household level are intrinsically linked and proportional. The relationship between per capita household livestock wealth and overall household livestock wealth is examined further in Chapter 4. No correlation was found between household size and the number of small ruminants owned by the household, which demonstrates that these are secondary to the overall household economy.

4 Chapter 4 Socioeconomic characteristics of households

4.1 Introduction

In this chapter the relationshop between social organisation and household economy in KGR households is explored. Pastoralist livelihoods are in a transitional state and an understanding of the social and economic context of pastoral communities and their livelihood strategies is key to achieving sustainable, effective disease control through the rolling out of culturally-accepted and context-appropriate interventions. Feasible control requires a deep understanding of the system and all its elements, comprising human, animal and environmental components. An appreciation of the domestic/internal social organisation of households is key to this systems approach "*…the structure and function of groups that work and live together seem particularly pertinent to an understanding of the pastoral ecosystem at large*" (van Raay, 1975).

An assessment of variation in KGR household characteristics (household size, composition and economy) was made, followed by a categorisation of households using proxies for wealth status to explore variation in sources of income and livelihood diversification. Findings across three survey periods were compared. Data was compiled from questionnaires and from the application of participatory methods within the Fulani community. Fulani household size, composition, livelihood strategies and household economy are explored and interpreted within the context of knowledge of the internal social organisation of Fulani households and the literature.

4.2 Aims and objectives

This chapter is subdivided into three sections that answer the following questions.

I. Wealth status and poverty

- What is the wealth status of people in KGR - how many are poor or wealthy?
- How does the wealth status of people vary across blocks and since settlement in KGR? (The very small sample in Block 5 and Block 6 make this difficult for these blocks, however, comparison of Block 1, 2, 3 and 4 is undertaken).
- What is the relationship between HH size and livestock ownership?

- Are household possessions, building type and number good wealth indicators?
- What is a good proxy for wealth status in the KGR context? (This could become a circular argument as wealth status is derived from a series of proxy measures in the first place. This is avoided by confirming indices of wealth with community members through FGDs).

II. HH size and composition

- How do HH size and polygyny vary with block and time since settlement in KGR?
- Is there an association between HH size or polygyny and wealth status?
- Is there an association between HH size and age of HHH?

III. Livelihood strategies

- To what extent are KGR pastoralists diversifying their livelihoods (i.e. how much of their income is derived from crop farming and/or off-farm activities)? This is not a longitudinal study hence the level of diversification is compared against the baseline of traditional or 'pure' pastoralism, whereby households depend 100% on revenues from livestock.
- How are the different livelihood strategies influenced by wealth status?
- Does household milk sale or crop sale vary across blocks, with time since settlement in KGR or with wealth status?
- Does the uptake of off-farm sources of income vary with block, time since settlement in KGR or with wealth status?
- Does the receipt of money from family members living outside of KGR vary with block, time since settlement in KGR or with wealth status?

4.3 Materials and methods

4.3.1 Questionnaire administration

This study draws upon the surveys undertaken in KGR at three different time points: March 2011, June 2011 and October 2011. Information on the sample design of each survey has been covered in Chapter 2 (2.2.3 Original sample design March survey;

2.2.3.4 Deviation from original protocol; 2.2.4 Sample design June and October survey; 2.2.4.2 Deviation from original sampling protocol).

Briefly, for the March survey 64 households were randomly selected using the generation of random numbers between 1 and 581 (total number of households in KGR as defined in July 2010 census). For the June and October surveys 40 households were randomly selected using the generation of 40 random numbers between 1 and 724[2] (total number of households as defined in June 2011 census). Random numbers were generated in Survey Toolbox®. In October, 80 households were sampled, including the 40 which had already been sampled in June and an additional 40 households randomly selected from the sampling frame of 724 households, less the 40 households previously sampled in June (see Chapter 2).

A questionnaire was administered to each randomly selected household during each survey. The households selected were also sampled for animal and/or human disease screening but this data is not discussed in this chapter.

The number of questionnaires and households sampled for each survey is summarised in Table 9. Not all households randomly selected for sampling agreed to be interviewed, explaining the difference between the number of households sampled and number of households for which questionnaire data is available. During the October survey, half of the 80 households were identical to those sampled and interviewed in June, hence only the new sections of the questionnaires were administered to these households. The remaining 'new' 40 households were administered all sections of the October survey questionnaire.

Table 9 summarises the number of new immigrant households and settled households sampled in each survey. New immigrant households are families that moved to the KGR after the election violence of April 2011. Settled households refer to households who had settled in the KGR before 2011. Around 30% of households in the June and October surveys were new immigrants. The March 2011 survey was conducted before mass influx of immigrants and all were 'settled' households.

[2] This number is lower than the 777 as 53 households visited during the census refused to participate in the study and were therefore removed from the sampling frame.

BLOCK	1	2	3	4	5	6	Total
March 2011							
N HH sampled	18	28	13	4	1	0	64
N HH interviewed with questionnaire	16	25	11	4	1	0	57
June 2011							
N HH sampled & interviewed	6	14	6	9	4	1	40
N HH moved <2011[1]	3	10	3	5	3	0	24
N HH new immigrants (moved 2011)[1]	2	3	3	4	1	1	14
October 2011							
N HH sampled & interviewed (new sections)	13	30	13	17	5	2	80
N HH interviewed (all sections)	7	16	7	8	1	1	40
N HH moved <2011[2]	5	15	2	4	1	1	28
NHH new immigrants (moved 2011)[2]	1	1	5	4	0	0	11

Table 9 Number of households sampled and interviewed during the March, June and October 2011 surveys across the 6 blocks and overall

[1] Two HH did not specify year moved to KGR; [2] One HH did not specify year moved to KGR

4.3.2 Data analysis

Association between predictor variables and response variables were examined using analysis of variance (one-way ANOVA) and the non-parametric test Kruskal-Wallis in Minitab® (Table 10). Kruskal-Wallis tests the equality of medians of two or more populations (Null hypothesis or H0: the population medians are all equal versus; Alternative hypothesis or H1: the medians are not all equal). ANOVA tests the hypothesis that the means of two or more populations are equal (H0: all population means are equal; H1: at least one population mean is different).

Response variables		*Predictor variables*	
Qualitative	Quantitative	Qualitative	Quantitative
HH participation in salaried work	Hectares farmed	Block	Year HH moved to KGR
HH participation in business	Milk sale	New immigrant HH vs Old settler HH	TLU/HH[1]
HH participation in waged-work	Number of HH possessions		TLU/capita[2]
HH receipt of money from family members living outside KGR	Age of HHH		HH size[3]
	Number of wives of HHH		
	TLU/HH[1]		
	TLU/capita[2]		
	HH size[3]		

Table 10 Qualitative and quantitative response and predictor variables investigated for association

[1] TLU per household was derived by multiplying the total number of cattle by 0.7, small ruminants by 0.1 and domestic fowl by 0.01

[2] TLU per capita was derived by dividing TLU/HH by HH size

[3] HH size is the number of persons living in the household, including the HHH

One-sample t-test was used in Minitab® to derive a t-confidence interval to compare sample means from different populations. Overlap in confidence intervals indicates the sample means are not significantly different. The sign test was used as a non-parametric alternative to a 1-sample t-test to compare the sample medians of different populations. Correlations were investigated in Minitab® by calculating the Pearson product moment correlation coefficient and its non-parametric equivalent, the Spearman's rank correlation coefficient between pairs of variables (Table 10). The Pearson product moment correlation coefficient measures the degree of linear relationship between two variables. Spearman's rank correlation coefficient is also a measure of the relationship between two variables. However, Spearman's rank correlation coefficient was calculated on ranked data.

Data were plotted in scatterplots to investigate correlation. A least squares regression line were added to scatterplots in Minitab® to examine the relationship between the response (y) and predictor variable (x). The model order for the regression fit included linear, quadratic and cubic and was calculated in Minitab®.

4.3.3 FGDs and KIIs

Data was gathered during focus group discussions and from key informant interviews. The topics and target groups/individuals relevant to this chapter are summarised in Table 11.

Topic	*Target*
FGD	
Community wealth ranking	Men and women
Sale of dairy products	Members of women's cooperative
Consumption and processing of milk (from cow to mouth)	Women (housewives) Men (pastoralists)
Household composition	Women
KII	
Crop farming, KGR past and future	Elderly, educated, elite male; advisor to district head (Damina Abdulahi)

Table 11 FGD and KII topics and corresponding target groups/individuals

4.3.4 Questionnaire respondents

Respondents for all three surveys were male, 77.2, 77.5 and 74.4% of which were household heads (HHH) in the March, June and October 2011 respectively. The

remaining 25% were either junior brothers or sons of the HHH. The highest level of education for the majority of respondents (75, 82.5 86.6% in March, June and October 2011 surveys respectively) was completion of Koranic school. Other education levels were primary, secondary school and higher. The mean and median age of respondents was 47 and 50 (March), 48 and 46 June, and 48 years for October. The age range of respondents was between 20 to 87 years.

4.4 Wealth status and poverty

Pastoral societies should not be considered egalitarian in nature, as variations exist in household economy and resource-management strategies (Tewolde, 2010, Spencer, 2005). There is an erroneous belief that equality, in terms of wealth and livestock ownership, exists in pastoral communities and that consumption levels are similar across different households (Tewolde, 2010). It is important to distinguish between tmechanisms which exist in pastoral communities to prevent permanent inequalities, such as transfer of assets, limitations in herd size imposed by family labour, and actual distribution of livestock and wealth between households (Sutter, 1987).

Many authors attest that '*insufficient attention has been paid to the disparities in livestock ownership and wealth differentiation'* (Little, 1982, Bassett, 1986, Tewolde, 2010, Asad, 1979). Manger asserts that '*economic inequality is a common feature among pastoralists, grown out of historical internal dynamics and unequal access to external sources*' (Manger, 2000). Konczacki (1978) suggests '*the prevailing pattern of wealth, and consequently income distribution, among African societies dependent on animal husbandry, is one of inequality*'.

Another misconception is the generalisation that all pastoralists are poor and that their out dated livelihood generates impoverishment (Little et al., 2008). Some authors have described that a decrease in household wealth or an increase in household requirements favours a shift from pastoralism into agro-pastoralism and that increasing wealth is more likely to be associated with accumulation of livestock than with increasing agriculture (Mace, 1993). Tache and Sjaastad (2010) propose that '*the livestock holding, particularly cattle, is the node that ties different aspects of wealth and poverty together'* in pastoralist communities.

Livestock ownership ensures food security, asset protection, and insurance against shocks. Quantification of livestock capital is a proxy of household wealth for pastoralist communities. For agro-pastoralist communities, land holding is also an indicator. Households within the KGR do not own the land they cultivate and so hectares of land farmed was not taken into consideration for the overall household wealth assessment. This has limitations, partly addressed by comparing agricultural and off-farm sources of income across households of varying livestock wealth status to assess whether these activities 'top-up' livestock-derived household income.

Quantitative analysis of wealth status and poverty is a complex issue (Tache and Sjaastad, 2010). Poverty conceptions are context-specific and those appropriate for sedentary agricultural or urban settings (measures of income and expenditure) are not appropriate for societies outside of the cash economy as are the KGR community (Little et al., 2008). When assessment of income and expenditure is not appropriate to context, asset possession provides a better evaluation of household wealth. This also has limitations in situations when ownership is diffuse or when informal asset sharing and caretaking arrangements are common (Tache and Sjaastad, 2010). An approach to assess wealth and poverty across communities is participatory wealth ranking, whereby key informants determine the reference points they themselves (Tache and Sjaastad, 2010). FGDs revealed that the number of animals is the single most important parameter to rank a household's wealth status at the KGR community level, which is in agreement with the findings of Tewolde (2010) Adunga (2013).

Measuring poverty and wealth in pastoralist societies is complex as herds fluctuate over time and the extent to which pastoralism contributes in a mixed economy varies between societies (Spencer, 2005). Polygamy data can provide a comparable index across different pastoral groups. There is no 'one-size fits all' approach to analysing poverty and wealth, but categorisation of wealth status according to livestock capital has been validated in pastoralist systems (Little et al., 2008).

In this section we endeavour to estimate the wealth status of households, social stratification and wealth heterogeneity in KGR. This is prone to potential bias due to the complexity of livestock ownership within Fulani communities and quantified wealth estimates are 'approximate'.

4.4.1 Variations in household wealth in KGR

The total number of livestock units in a household can be used to estimate the wealth of pastoralist households. The sample households of each survey were described in terms of wealth using the combined approach for classification of Potkanski (1997) and McCabe et al. (2010), based on Tropical Livestock Units (TLU) per capita. TLU per household was derived by multiplying the total number of cattle by 0.7, small ruminants by 0.1 and domestic fowl by 0.01 (Jahnke et al., 1988) and summing individual values. The TLU per capita was calculated by dividing the total TLU per household by the number of persons living in that household (household size). TLU/capita values classified households as destitute, very poor, poor, medium, moderately wealthy and wealthy (see Table 12). TLU per capita was used as a proxy for household wealth based on 132 out of 136 households ranking livestock as the most important contributor to household income (Table 24).

Wealth category	*TLU/capita*
Destitute	<0.49
Very poor	0.50-1.24
Poor	1.25-2.49
Medium	2.50-4.99
Moderately wealthy	5.00-9.99
Wealthy	>10.00

Table 12 TLU/capita values used to define wealth categories

TLU per capita and TLU per household co-vary (Figure 38), and the relationship is curvilinear (Figure 39). The Pearson and Spearman's rank correlation coefficients were found to be 0.442 (p=0.000) and 0.769 (p=0.000) respectively for all pooled data from the March, June and October surveys. Correlation was also calculated for the data minus the outlier household that owned 1500 cattle and had a household size of 270 people. Pearson and Spearman's rank correlation coefficients were found to be 0.630 (p=0.000) and 0.770 (p=0.000). The curvilinear relationship observed in Figure 39 suggests that after a certain threshold, the per capita wealth of individuals in rich households is not proportionally greater than that of poor households. Households with more livestock wealth have more people (there is a positive and statistically significant correlation between household size and TLU/HH and household size and number of cattle owned by household, see Table 18).

Once households have approximately 6 TLUs per householder further increase in household wealth does not lead to further increase in household wealth does not lead to further increase in per capita wealth for existing household members. This was also reported by Sieff (1999) who found that beyond 5 TLUs per capita, further increases in household wealth did not result in an increase in wealth per capita.

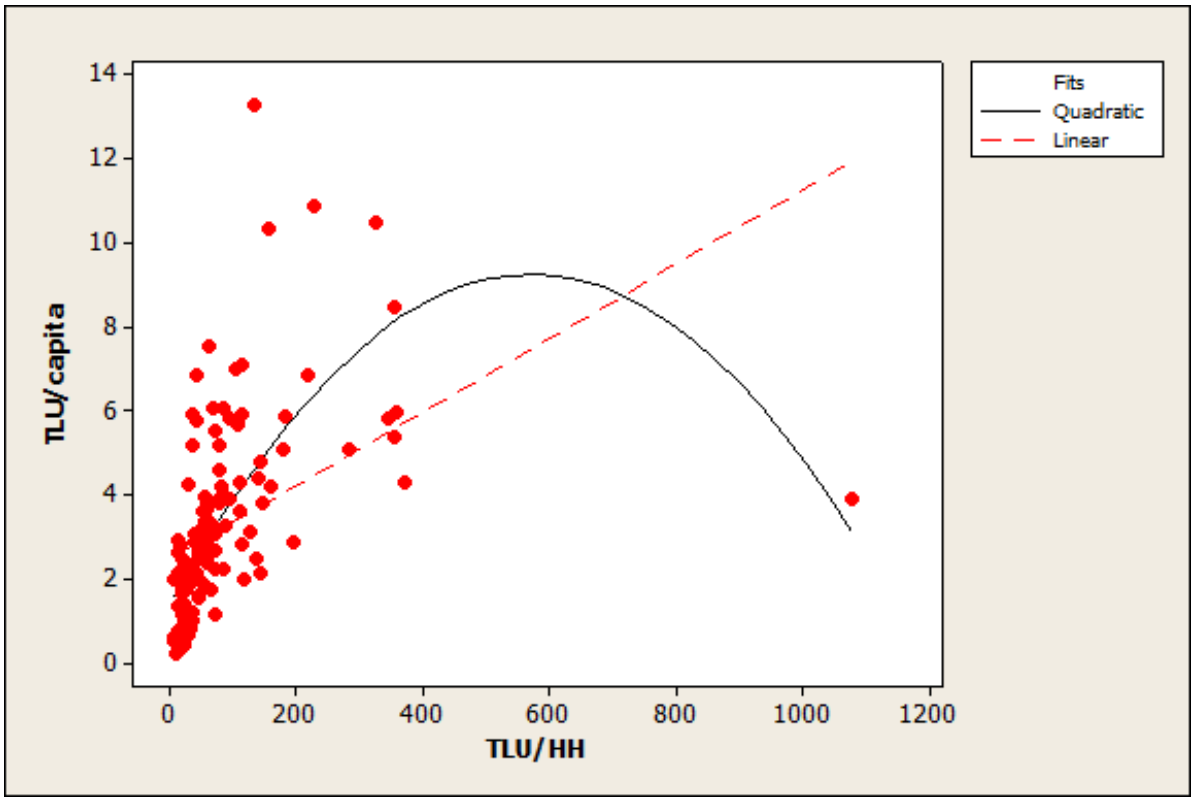


Figure 38 Relationship between TLU per household and TLU per capita for households sampled during March, June and October surveys

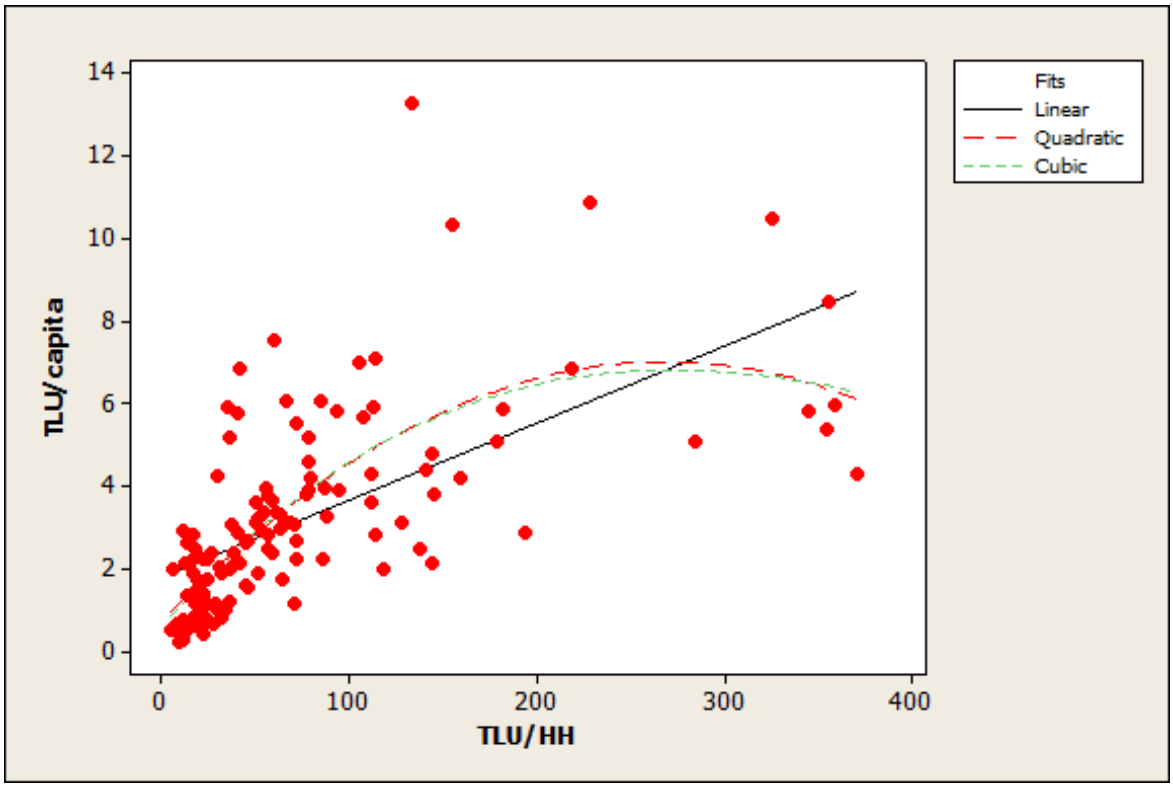


Figure 39 Relationship between TLU per household and TLU per capita minus outlier household

There are pros of using either the TLU/HH or the TLU/capita as proxy. TLU/HH gives a better appreciation of production dynamics affected by economies of scale while TLU/capita gives an appreciation of the resources available in terms of meat, milk and purchasing power. Sieff states '*if the viability of households ultimately depend on the daily provisioning of residents, then per capita wealth will be a better indication of a household's prospects than the total number of livestock units'* Sieff, 1999). Per capita wealth also explains the variation in household subsistence strategies better than does total household wealth (Sieff, 1995).

The number and distribution of KGR households in each wealth category is summarised in Figure 40. Table 13 shows that 34% of households are in the medium wealth category. Approximately 50% are categorised as poor, very poor or destitute. Only 20% are considered moderately wealthy. This is similar to a study of the Borana pastoralist communities in Ethiopia where 80% were considered to be living in poverty (Manger, 2000). A per capita of between 4 and 5 TLU are needed to sustain a livelihood as a pastoralist (Fratkin and Roth, 1990). More than half of the

population in KGR are struggling to sustain a livelihood and are either in the process of going downwards on the poverty spiral, or are deriving income from another source. The potential for income diversification as a coping strategy is considered below. TLU per capita is used to compare wealth across the different blocks and explore livelihood diversification. In the sections considering indicators of wealth, proxies of poverty and livelihood diversification the association of specific factors to both TLU/capita and TLU/HH is explored.

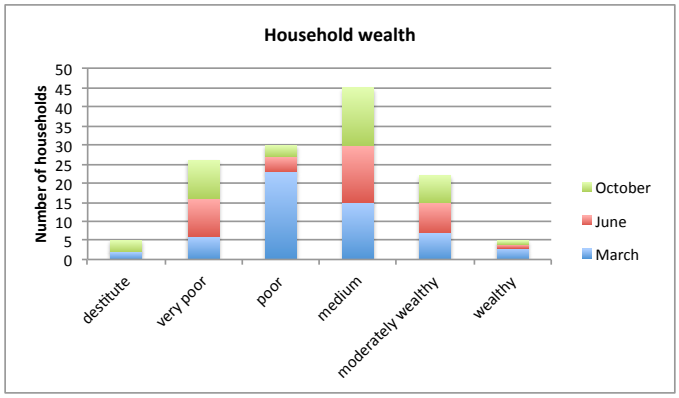


Figure 40 Number of households in each wealth category for March, June and October surveys

Wealth Category	*N HH*			*TOTAL HH*	*%*
	March	June	October		
Destitute	2	0	3	5	3.8
Very poor	6	10	10	26	19.5
Poor	23	4	3	30	22.6
Medium	15	15	15	45	33.8
Moderately wealthy	7	8	7	22	16.5
Wealthy	3	1	1	5	3.8
Grand Total	56	38	39	133	100

Table 13 Number and percentage of households in each wealth category

Figure 41 illustrates the percentage of households in each wealth category for each block. Block 1, inhabited by community leaders and elite community members is on average the 'wealthiest' block. Block 2, on the contrary, is characterised as the poorest, with Blocks 3 and 4 between these two. Too few households were sampled from Blocks 5 and 6 but the few households sampled were wealthier than those in Block 2 and some were equivalent to Block 1. The households sampled during the March survey give a similar pattern except for Blocks 1 and 2, for both June and

October surveys. Block 2 has either a lower percentage of very poor households or a higher percentage of wealthy households in those two surveys. Block 2 contains affluent households living close to the market area and poor households living furthest away from the market. More affluent households closer to Tampol may have been sampled during June and October than in March. Surveys in June and October incorporated new immigrants that moved into KGR after the election violence, households with a higher wealth status overall (Figure 42). The higher wealth status of newer households is more apparent in the survey in June than October 2011.

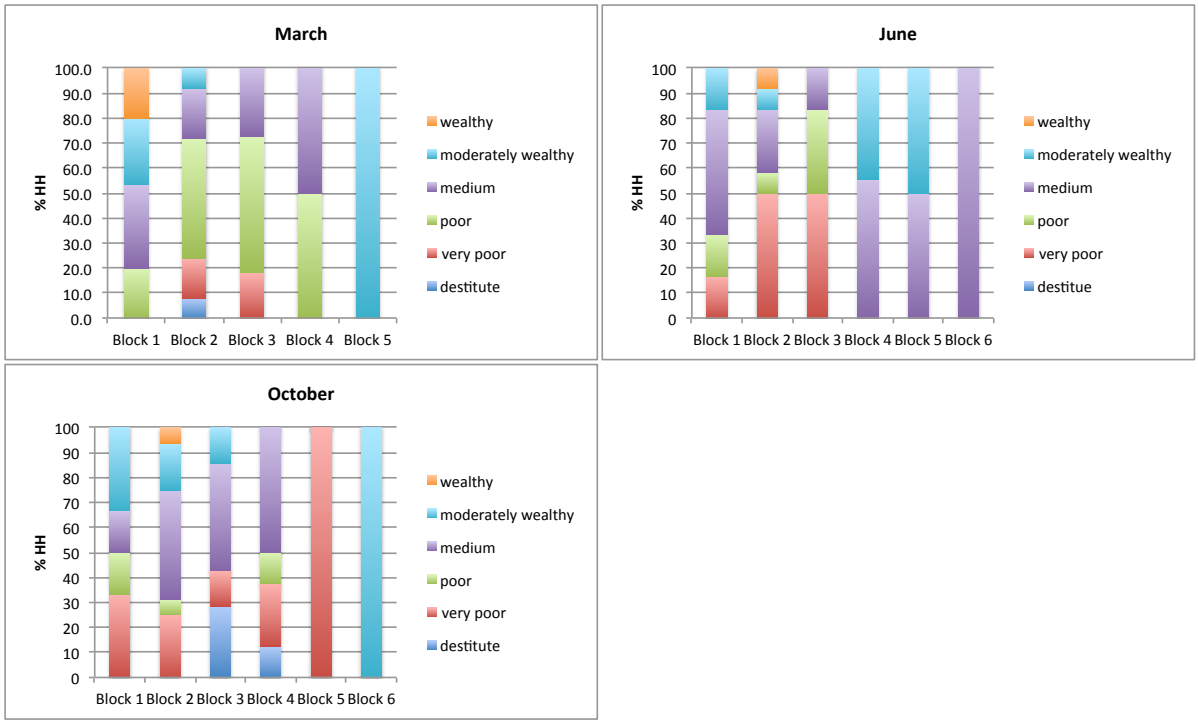


Figure 41 Percentage of households in each wealth category for each block

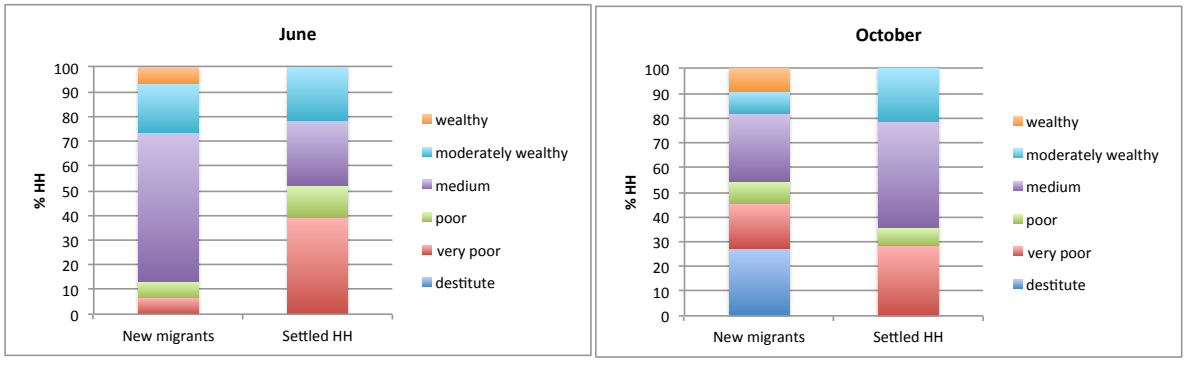


Figure 42 Percentage of HH in each wealth category for new immigrant and settled households

Wealthiest households (in Block 1) and those living adjacent to the market area in Block 2) may have differential access to pasture and amenities. In KGR these households exercise their superior status by settling within proximity of the community amenities and market hub of Tampol.

The association between TLU/capita and block was investigated for pooled data from March, June and October. The p values (0.018 and 0.016 for the one-way ANOVA and Kruskal Wallis tests respectively) indicate that there is sufficient evidence not all TLU/capita means and medians across blocks are equal when alpha is set at 0.05. The means and medians and respective confidence intervals for TLU/capita across blocks are summarised in Table 14. Although there is overlap in the confidence intervals, Block 1 and 4 have higher mean/median TLU/capita than blocks 2 and 3, which is in agreement with what was reported in Chapter 3 for the census data.

The association between TLU/HH and block is similar to that observed for TLU/capita (One-way ANOVA: p=0.054; Kruskal-Wallis: p=0.017). Means and medians and respective confidence intervals of households in different blocks are summarised in Table 15, and show Blocks 1 and 4 with higher mean and median TLU/HH than Blocks 2 and 3.

Comparison of TLU/capita for old settlers and new immigrant households for pooled June and October data revealed that p values (0.279 and 0.397 for one-way ANOVA and Kruskal-Wallis respectively) are insufficient evidence to support that means are different when alpha is set at 0.05. The means and medians and respective confidence intervals of new immigrants and old settler households are summarised in Table 16, and show that new immigrants have higher mean and median TLU/capita.

There is a statistically significant difference in mean and median TLU per household between new immigrants (household that moved to KGR in 2011) and old settlers (households that settled in KGR prior to 2011): Kruskal-Wallis (H=8.09, DF=1, p=0.004)); ANOVA (DF=1, F=9.29, p=0.003). P-values (0.003, 0.004) indicate there is sufficient evidence that not all means are equal when alpha is set at 0.05. The means and medians and respective confidence intervals of new immigrants and old settler households are summarised in Table 17, and show that new immigrants have higher mean and median TLU/HH.

Households that moved into the KGR in 2011 had greater livestock wealth than those settled prior to this date. These households may be wealthier in terms of livestock assets, or are set up as a single 'wuro' unit, not yet having had the opportunity to subdivide into individual self-sufficient 'ruga' (see Chapter 3).

Block	*N HH*	*1-sample sign*		*1-sample t*	
		Median TLU/capita	95% CI	Mean TLU/capita	95% CI
1	28	4.007	(2.434, 5.102)	4.221	(3.062, 5.381)
2	53	2.158	(1.461, 2.843)	2.779	(2.121, 3.436)
3	24	1.945	(1.104, 2.465)	2.108	(1.584, 2.633)
4	21	3.087	(2.490, 4.052)	3.234	(2.395, 4.073)
5	6	4.318	(1.483, 5.955)	4.004	(1.811, 6.197)
6	2	4.674		4.67	(-22.86, 32.21)
Total	134				

Table 14 Mean and median TLU/capita and confidence intervals across blocks

Block	*N HH*	*1-sample sign*		*1-sample t*	
		Median TLU/HH	95% CI	Mean TLU/HH	95% CI
1	27	71.1	(50.0, 133.3)	87.6	(63.7, 111.5)
2	53	30.5	(22.6, 50.5)	58.3	(38.9, 77.7)
3	24	34.7	(24.3, 61.2)	58.8	(32.2, 85.4)
4	19	66.5	(45.7, 93.2)	146.0	(27.4, 264.7)
5	6	67.0	(27.2, 357.4)	150.9	(-18.0, 319.8)
6	2	89.5	NA	89.5	(-525.8, 704.8)
Total	134				

Table 15 Mean and median TLU/HH and confidence intervals across blocks

Year moved to KGR	*N HH*	*1-sample sign*		*1-sample t*	
		Median TLU/capita	95% CI	Mean TLU/capita	95% CI
2011 (new immigrant)	23	3.124	(2.590, 4.054)	3.752	(2.610, 4.893)
<2011 (old settler)	51	2.939	(1.736, 3.597)	3.105	(2.478, 3.732)
	74				

Table 16 Mean and median TLU/capita and confidence intervals for new immigrant versus old settler households

Year moved to KGR	*N HH*	*1-sample sign*		*1-sample t*	
		Median TLU/HH	95% CI	Mean TLU/HH	95% CI
2011 (new immigrant)	23	79.5	(61.8, 165.1)	171.1	(73.3, 268.8)
<2011 (old settler)	51	44.5	(32.0, 60.2)	65.3	(45.3, 85.2)
	74				

Table 17 Mean and median TLU/HH and confidence intervals for new immigrant versus old settler households

4.4.2 Indicators of wealth and proxies of poverty

To evaluate the variables, such as number of buildings, number of wives and number of possessions as proxy indicators of wealth or poverty, the Pearson correlation coefficient was used to investigate correlation between the TLU/capita and TLU/HH and specific variables (Table 18). Correlation between household size (number of persons living in household) and specific variables was also investigated.

TLU/HH is positively correlated and significant at the p=0.001 with household size (Table 18). There is no correlation, however between household size and TLU/capita (Table 18). This is due to the curvilinear relationship described between TLU/HH and TLU/capita (Figure 39), and the fact that the per capita wealth of individuals is not proportionally greater than that of poor households. This relationship explains why proxies of household wealth such as number of possessions, number of buildings in homestead and number of wives of household head are positively correlated (and statistically significant) with TLH/HH but not with TLU/capita (although number of wives is positively correlated and statistically significant with TLU/capita for the March 2011, survey). Better off households have a larger household size than poor households, and have attributed this to wealthy households having a better opportunity for polygamy than their counterparts (Adunga, 2013).

Possessions (mobile phones, radio, maize grinder, motorcycles and bicycles) and number of buildings were positively correlated with TLU/HH and were significant (p=0.05, 0.01 or 0.001 levels), in one or more survey. Statistically significant correlation was not obtained across all surveys - these variables are not consistently good proxies of wealth in the pastoralist context and their use should be restricted. Motorbikes were the only possession positively correlated with TLU/HH and statistically significant across all three surveys. Simple indicators of cash earnings or expenditures offer only weak proxies for household wealth status (Little et al., 2008).

The correlation of possessions and number of buildings with household size was examined to demonstrate the association between livestock wealth, household size, and number of possessions. Households with larger cattle herds can support more people, the larger household size means that more buildings are required to house

householders, more householders means a greater demand for possessions. Number of livestock, or number of cattle (as cattle contributes the most to the TLU/HH), number of persons in household, number of buildings and number of possessions are inter-related and proportional. TLU/capita is not proportional to number of possessions and buildings since after a threshold of 6 TLU/capita, further increases in household wealth do not lead to further increases in per capita wealth for existing household members.

Pair of variables	*March*	*June*	*October*
TLU/capita & TLU/HH	0.612*	0.329***	0.738*
TLU/capita & various			
TLU/capita & wives HHH	0.469*	0.22	0.177
TLU/capita & sofa	NA	0.14	0.02
TLU/capita & radio	NA	0.15	-0.009
TLU/capita & mobile	NA	0.085	0.074
TLU/capita & maizegrinder	NA	0.129	-0.215
TLU/capita & bicycle	0.12	0.079	-0.249
TLU/capita & motorcycle	0.173	0.199	0.224
TLU/capita & buildings	0.202	0.069	0.128
TLU/HH & various			
TLU/HH & wives of HHH	0.490*	0.588*	0.381**
TLU/HH & sofa	NA	0.039	0.115
TLU/HH & radio	NA	0.864*	0.270
TLU/HH & mobile	NA	0.802***	0.325***
TLU/HH & maize grinder	NA	0.336***	-0.193
TLU/HH & bicycle	0.560*	0.244	-0.049
TLU/HH & motorcycle	0.669*	0.403**	0.496*
TLU/HH & buildings	0.474*	0.923*	0.175
HH size & various			
HH size & bicycle	0.558*	0.456*	0.054
HH size & motorcycle	0.736*	0.567*	0.414**
HH size & maize grinder	NA	0.246	-0.019
HH size & mobile	NA	0.111	0.453***
HH size & radio	NA	0.223	0.390**
HH size & sofa	NA	0.278***	-0.025
HH size & buildings	0.653*	0.783*	NA
HH size & cattle	0.672*	0.764*	0.465*
HH size & TLU/HH	0.675*	0.761*	0.481*
HH size & TLU/capita	-0.022	0.004	-0.074

Table 18 Pearson's rank correlation coefficients for pairs of indicators for households sampled during the March, June and October surveys

*significant at 0.001 level; **significant at 0.01 level; ***significant at 0.05 level; NA not applicable

4.5 Household size and composition

Households are described as a locus of production, distribution, transmission, reproduction and co-residence (Wilk and Netting, 1984, Roberts, 1991). Historically,

the traditional domestic unit (linked by various obligations and forms of cooperation) consisted of agnatic lineages, described as primary kinship groups of 500-1000 persons (Bonfiglioli, 1993), whose common ancestor could be traced back through more than seven generations (Awogbade, 1983). Fulani social organisation has changed with the shift from nomadic to semi-nomadic lifestyle. The major unit of domestic organisation for settled Fulani, such as those in the KGR, consists of an atomistic semi-nomadic camp referred to as a *wuro* or household (Awogbade, 1983).

A household or *wuro*, is typically a group of agnatically related men, with their wives and children, extending over two or more generations (Hampshire, 2006). The starting point in the cycle of household development and the foundation of social and economic life is the household head (the *jewuro*) and his first wife. The drivers for household division and formation are complex. In the first stage, the household expands through the offspring of the *jewuro* and his first wife, and may continue to expand and form a compound family if the *jewuro* takes on more wives (up to a maximum of 4 wives). The household will enter a second phase of expansion when sons of the *jewuro* take wives of their own and have children. At this time the household enters a division phase, as sons with wives may separate from the household of their father. Adult daughters will marry and leave the homestead of their father to live with the family of their husband. As sons build up large enough herds they will separate from the household of their father. The eldest son has the responsibility to look after his elderly father and his wives. Dissolution occurs when all sons have married, or if the household head dies and his herd is distributed among the sons and daughters, in a 2:1 ratio (van Raay, 1975).

There are certain factors that make division more likely, such as death of a father, absence of older brothers and wealth status. There exists a cow-human equilibrium since it is the size and structure of the household that dictates whether the household and herd functions as a viable unit (van Raay, 1975). Despite livestock ownership being the most important element of wealth, other aspects include *"wealth in people"* which consists of the "*number of family members in a household"* or *"household size"* (Hampshire, 2002). Households with many economically active people have a greater productive and reproductive potential, since agro-pastoral

production is labour intensive (Hampshire, 2002). Wealth in people at a household level can be estimated by total household size, since most members (except the very young and old) are economically active. Wealth exerts an important effect on household division and formation (Hampshire, 2006). Wealthier households were found to be significantly larger than poorer ones, and a household with a large herd and/or successful agriculture provides a strong force making dividing and going off alone a less attractive prospect than it might be for a young man from a very poor household, for whom it might make sense to go it alone (Hampshire, 2006).

4.5.1 Household composition

Variations in household size and number of wives of HHH are explored in KGR to make inferences about potential differences in *wealth in people* between the different blocks, and between new immigrants and old settlers.

Household composition (and size) varies according to the stage of development of the domestic group. Households can be composed of a primary group +/- secondary group. The primary group comprises the HHH, his wives, children, and the wives and children of his married male children. The secondary group includes 'other' dependents, including siblings of the HHH and their wives and children, or even herd boys that are hired by the household to look after cattle (Awogbade, 1983).

Interviews with women enabled detailed family lineage to be established (men are not always aware of the matrimonial heritage of children). Two examples are presented here below, firstly a three-generation 'primary group' household where the household head is elderly and his sons are still living under his directive (Figure 43), and secondly a primary and secondary group household where the household head has died and been replaced by the eldest son, who still lives in the same household as his junior brothers, their wives and their children (Figure 44). Both households comprise just over 30 persons; households at different stages of development can be of the same size and the stage of household expansion/dissolution does not dictate the household size in terms of number of persons.

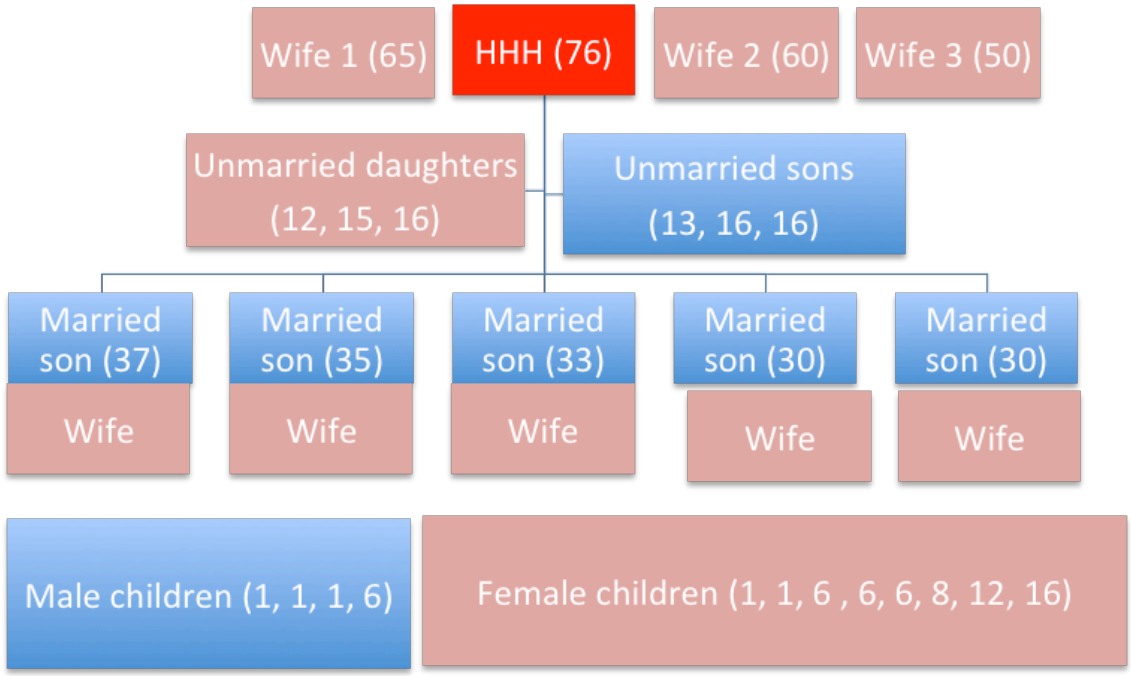


Figure 43 Composition of a three-generation household with elderly HHH

(number in brackets refer to age of person(s) in category)

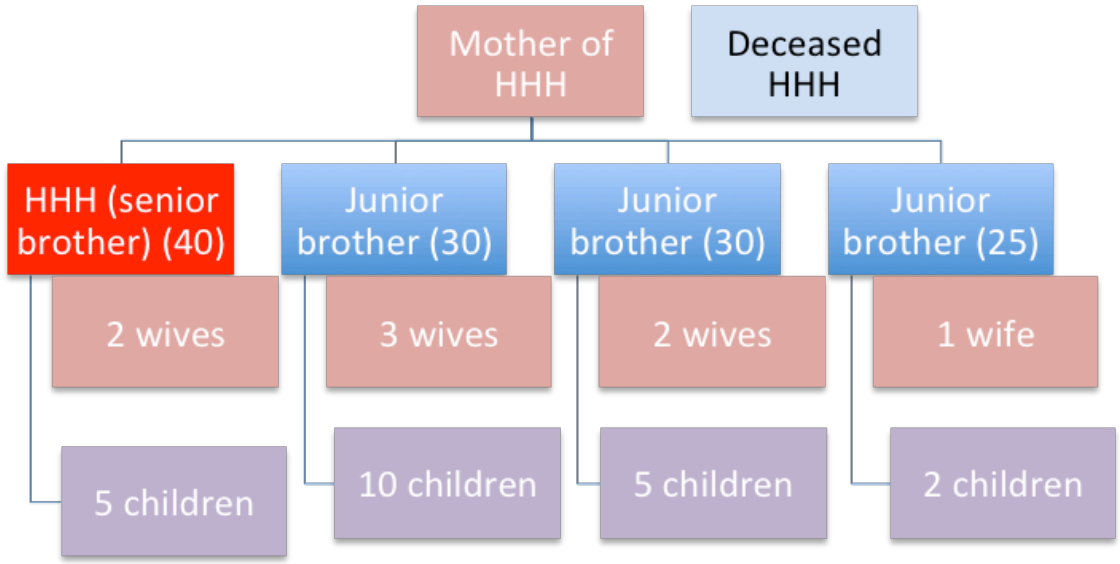


Figure 44 Composition of a two-generation HH with a younger HHH referred to as the 'senior brother'

(number in brackets refer to age of brothers)

The composition of the households sampled in the March (57 HH), June (39 HH) and October (39 HH) is summarised in Table 19. More than 50% of the household were

made up of children (similar to the 47.7% reported by Awogbade, [1983]). The large proportion of minors is not detrimental to the economic status of the household since most children over 8 years are economically active and engage in household activities such as crop farming and livestock rearing. The dependency ratio will be much lower than 50% if the economic contribution of the 8-55 age group is considered (Iro, 2009). The percentage of wives of HHH is approximately double that of the percentage of HHH. Hence HHH have on average two wives. The percentage of adult married males other than the HHH is equivalent to percentage of married adult females and so one can deduce that on average the brothers and sons of household heads only have one wife each.

Category	*Number (March)*	*% (March)*	*Number (June)*	*% (June)*	*Number (Oct)*	*% (Oct)*
HHH	57	5.0	39	3.0	39	4.1
Wives of HHH	112	9.8	84	6.4	75	7.8
Married adult males, brothers and sons HHH	114	10.0	153	11.6	97	10.1
Married adult females	129	11.3	169	12.9	127	13.3
Unmarried adult males	13	1.1	73	5.6	71	7.4
Unmarried adult females	5	0.4	51	3.9	46	4.8
Children (<18 y.o. March, <16 June, Oct)	714	62.4	746	56.7	503	52.5
TOTAL	1144	100.0	1315	100.0	958	100.0

Table 19 Composition of households sampled during the March, June and October surveys

To compare household composition across surveys, the total number of individuals in different categories (defined by relationship with HHH, age, sex and marital status) was divided by the number of household heads (equal to the number of households interviewed) for each survey to give a 'mean' number of individuals per category (Figure 45). Since categories for the March 2011 were more detailed than for June and October 2011 surveys, and age categories for children were slightly different, direct comparison of the March data with June and October is not possible.

A bar chart combining categories for the March data was prepared for comparison. Having more categories meant not all households had individuals belonging to the less common categories such as 'mother of HHH', 'cattle rearer', 'unmarried daughters and daughters over 18 years old', and so the mean number of individuals per household is under 1 for some of the categories of the March survey.

The 'average' household from the survey undertaken in March 2011 comprised one household head with a mean of two wives. This union will on average give rise to a mean of 11 children under 17 years old (2 babies under 1 year old, 4, children between 1-5 years, 3 children between 6-11 years and 2 children between 12-17 years per household). The questionnaires did not account for childhood mortality.

Three households out of 57 interviewed had one to three unmarried adult daughters and 7 households had one to three unmarried sons. Most daughters and sons will be married before the age of 18, and unmarried status after 18 years is more common for males than females. 36 out of 57 households (63%) include married sons and their wives (most sons have one wife). For households where an elderly household head has passed away and the oldest son takes over the head status from his father, the household composition will be described according to the head, his brothers and their wives. Six such households were interviewed during the March survey. The children of brothers and sons of the household head are categorised separately from the children of the HHH. With the passing of the household head, his widow is referred to as the mother of the HHH. In the March survey, 9 households hired non-blood related cattle boys and classified them as members of the household.

The 1:2 ratio of HHH to wives is consistent across surveys (Figure 45). The mean number of married males is slightly less than the number of married females, indicating that the majority of sons and brothers of HHH have one wife. Unmarried adults are rare and represent the smallest category (lower for women than men). Minors make up the largest category, with slightly more male than female children in the 5-15 year old category. The March survey shows children under 6, form the largest 'child' category, followed by 6-12 year olds and 13-17 year olds. The discrepancy between number of 1-6 year and 6-12 year old children may be due to high infant mortality, previously reported for Fulani households (Iro, 2009), unless children are leaving to join urban households with family no longer keeping cattle. The discrepancy between 6-12 and 13-17 year old categories may be due to older children, especially daughters, leaving the homestead for marriage.

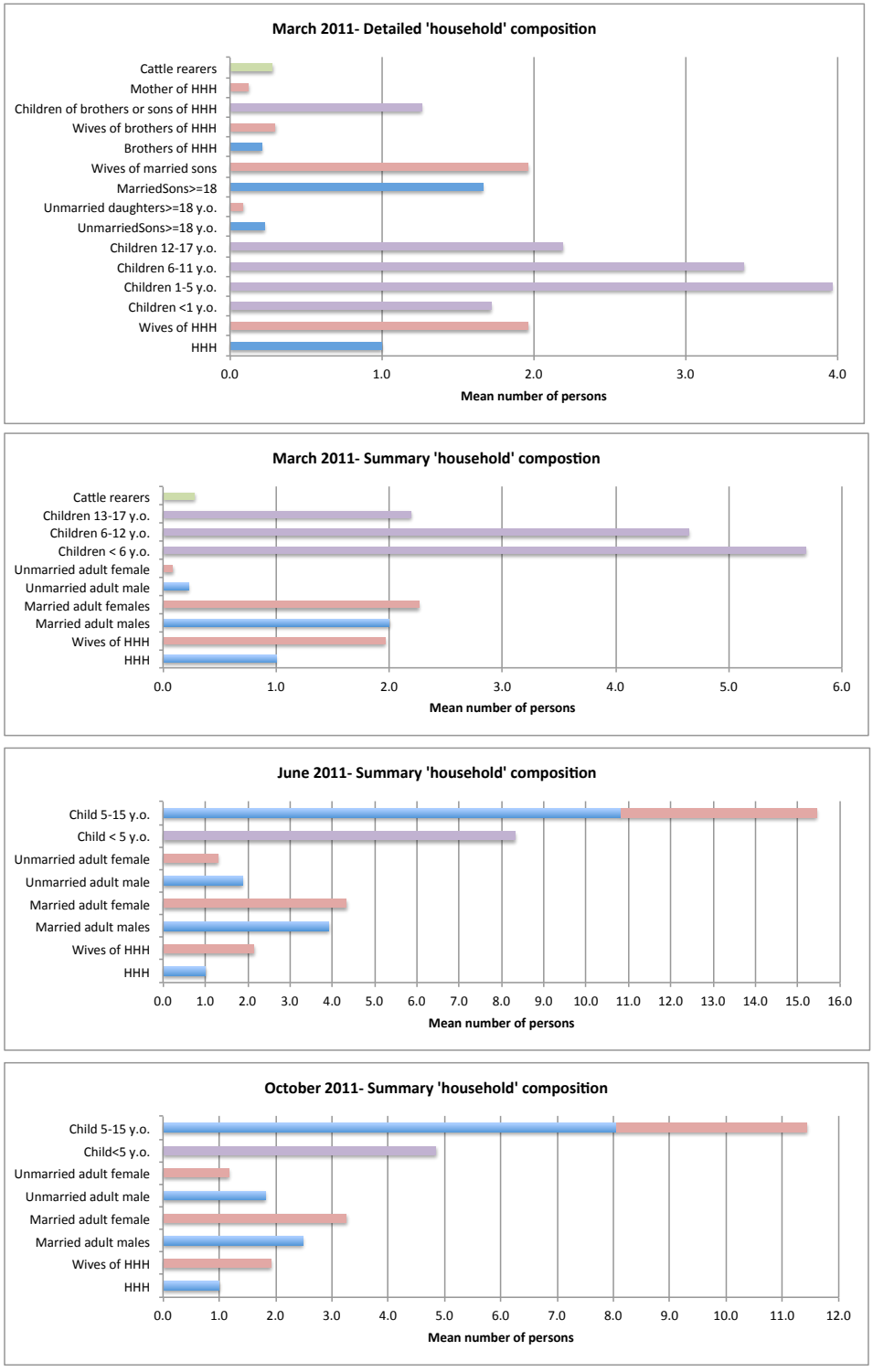


Figure 45 Mean number of persons in each category, from top to bottom: March, June and October surveys

(blue bars = males, pink bars = females, purple bars = male/female children, green bar=hired herdsmen)

4.5.2 Household head

The HHH or *jewuro* makes decisions on social, economic and political matters affecting the household. He controls the herding or agricultural unit and is responsible for the herd's safety, maintenance and reproductive efficiency (Awogbade, 1983, Hampshire, 2006). The remainder of the household are dependent on the HHH for economic, physical, moral support and for political representation.

A Fulani man must be thirty-five to forty years old to attain this status, whereas in the past it took only 25 years to achieve (Awogbade, 1983). In this study the ages of the HHH ranged from 23 to 87 years old. The mean and median age of the HHH was 53 and 53 (March) 53 and 50 (June) and 54 and 53 years (October). Rates of education (primary, secondary or further) other than Koranic schooling were low, standing at 19.3 (March) 12.5 (June) and 2.5% (October) of all household heads whose households were sampled for each separate survey.

Over 50% of the HHH were between 45 and 64 years old, similar to that reported previously (Awogbade, 1983). This is higher than reported in the 1950s (Hopen, 1958, Stenning, 1959) and may reflect social change as a result of sedentarisation or higher life expectancy.

There was no association between age of household head and household size. Household size does not grow exponentially over time as the *jewuro* ages, but rather divides when the optimum human to cattle ratio is no longer at equilibrium.

4.5.3 Wives, marriage and divorce

The number of HHH marriages is a strong proxy for household wealth due to the association between family and herd size and between prestige, polygyny[3] and large families (Spencer, 2005). A Fulani man, in accordance with Muslim doctrine, may take a maximum of four wives at any one time, but divorce enables men of high wealth status to take on a new wife if so desired. Men can re-marry if they are widowed, but ability to do this is dependent on wealth status. Marriage is costly since each bride comes with a bride price, which usually involves transfer of animals from the groom's family to the bride's family. Polygamy is a social marker for wealth.

[3] The state or practice of having more than one wife or female mate at a time, as opposed to polygamy which is the state or practice of being married to more than one person at the same time.

The number of wives of the household head (HHH) and the association between this and other factors was considered for the KGR.

Figure 46 shows that there are variations in the percentage of HHH with 0-10 wives between surveys, explained partly by sampling variation and different conditions between surveys. Conditions which are likely to account for these variations include: 1) households sampled during the March survey are those which did not send their whole herd on dry season transhumance (see Chapter 2) and are thereby more sedentary, as opposed to the surveys of June and October which included all households, including those that had just returned on dry/wet season transhumance; 2) households sampled during the June and October surveys included those of new immigrants who settled in the KGR in May 2011.

The mean number of wives of HHH and 95% confidence for the March, June and October surveys were 2.579 (2.191, 2.967), 2.526 (2.162, 2.891) and 2.051 (1.774, 2.329) respectively. Paradoxically the mean number of wives and their CI are more similar between the March and June surveys than between the June and October surveys. The lower mean of the October survey may be due to sampling variation.

Overall, the pattern of polygyny across the blocks is as follows (Figure 46). Block 1, regardless of the survey, always has a higher percentage of HHH with more than two wives than Block 2. Block 3 is similar to Block 1 in that it has a similar percentage of HHH with 1 or 2 wives. The pattern for Block 4 is inconsistent across different surveys and no conclusion can be drawn. Too few households were sampled from Block 5 and Block 6 to draw conclusions. Hence, the proportion of households with a HHH with three or more wives is highest in Block 1, followed by Block 3 and lowest in Block 2, which fits with the trends observed in census data (see Chapter 3).

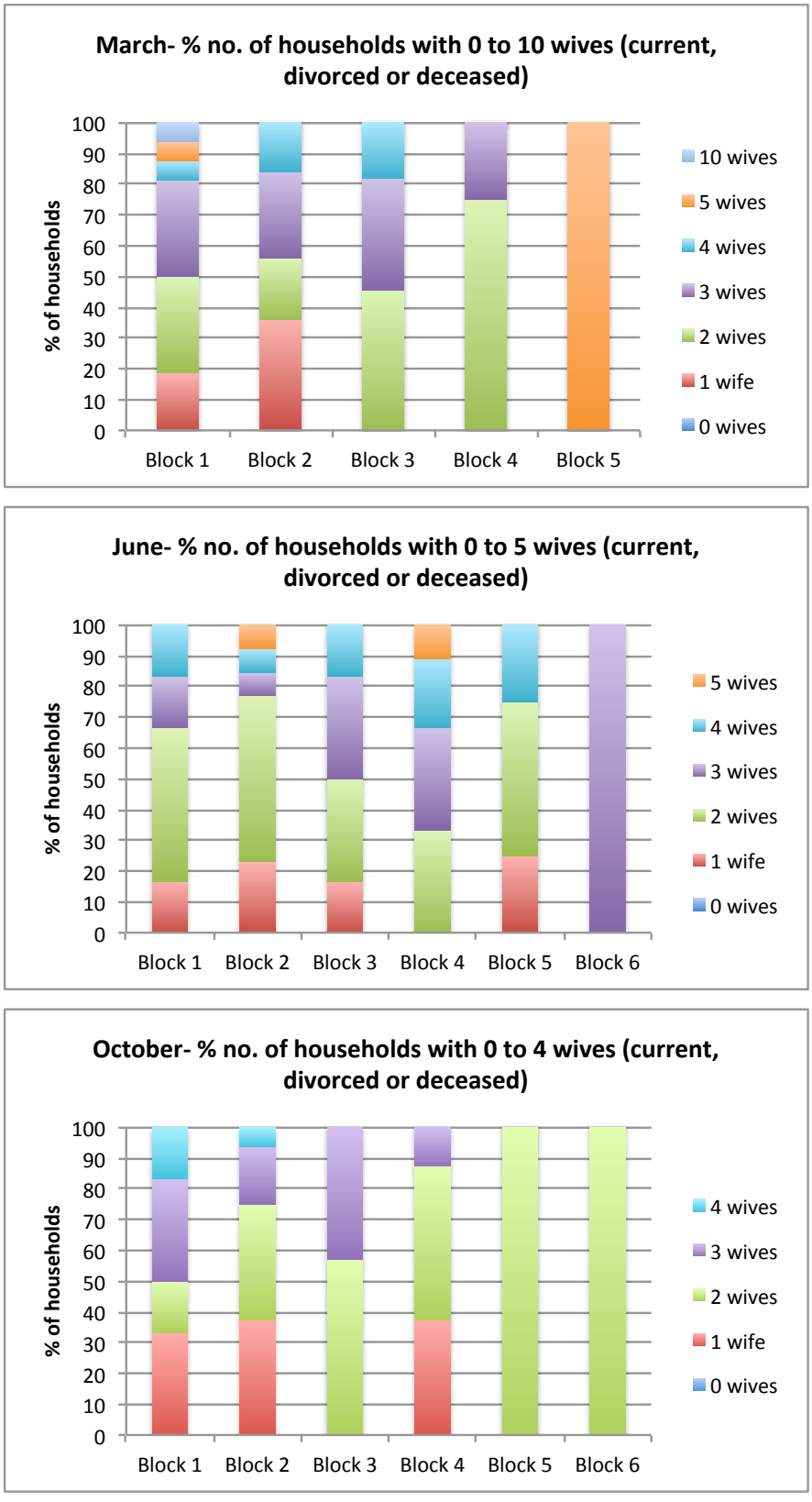


Figure 46 Percentage of HH with 0, 1, 2, 3, 4, 5 and 10 wives per HHH for each block

The association between block of origin and number of wives of HHH was examined by conducting a one-way ANOVA test on pooled data from the March, June and October surveys. The p-value was found to be 0.492 (>0.05) indicating that the block is not significant.

The mean (point estimate) number of wives of HHH and 95% confidence interval were calculated for each block using the 1-sample t procedure (Table 20). The confidence limits of the number of wives of HHH overlap for all blocks, showing that no conclusion can be drawn about an association between the two variables. The data shows, however, that the mean wives of HHH is highest for Blocks 1 and 3 and lowest for Block 2.

Block	*N HH*	*1-sample t*		*1-sample sign*	
		Mean wives	95% CI	Median wives	95% CI
1	28	**2.679**	(1.986, 3.371)	2	(2, 3)
2	53	2.151	(1.853, 2.449)	2	(2, 2)
3	24	**2.583**	(2.256, 2.911)	2.5	(2, 3)
4	21	2.429	(1.961, 2.897)	2	(2, 3)
5	6	2.667	(1.087, 4.247)	2	(1.4, 4.6)
6	2	2.500	(-3.853, 8.853)	2.5	NA
TOTAL	134	2.410	(2.201-2.620)		

Table 20 Mean and confidence interval for number of wives of HHH for each block

The association between livestock wealth in tropical livestock units (TLU/HH and TLU/capita) and number of wives of HHH was investigated for pooled data from the March, June and October surveys. The Pearson and Spearman's rank correlation coefficient were found to be 0.412 (p=0.000) and 0.462 (p=0.000) respectively indicating a moderately positive linear relationship between number of wives and TLU/HH. The correlation between number of wives of HHH and TLU/capita was also positive (Pearson correlation coefficient =0.324, p=0.000; Spearman's rank correlation coefficient=0.251, p=0.003). Hence as the number of cattle and to a lesser extent small ruminants and fowl and household wealth increases so does the number of wives of the HHH. Marriage necessitates the gifting of livestock, which means that ability to marry is linked to the number of cattle and small ruminants owned or wealth in terms of livestock.

The association between year household moved into KGR and number of wives of HHH was investigated, revealing a weak negative linear relationship between the two variables (Pearson correlation coefficient = -0.250, p=0.004). If number of wives of HHH is taken as a proxy of household wealth then the negative correlation suggests households that have settled in KGR the longest are wealthier. This fits with the previously discussed suggestion that the first settlers of KGR are more 'wealthy'.

Quadratic and cubic regression fits were plotted on a scattergraph in Minitab (Figure 47) revealing that a curvilinear relationship exists, with both very old settlers and new immigrants having HHH with a higher number of wives. This suggests, therefore, that for very new immigrants of 2011 the trend of increasing number of wives with time since settlement in KGR does not fit. Indeed difference in mean and median and corresponding 95% CI were calculated for new immigrant households versus those that moved to KGR prior to 2011 using the one-sample t procedure and one-sample sign test, and despite a slight overlap in CI for mean, the upper confidence limit and mean is higher for new immigrant households than old settlers (Table 21). The ANOVA test (p=0.104), however, did not indicate that the period of settlement was significantly associated with number of wives of HHH.

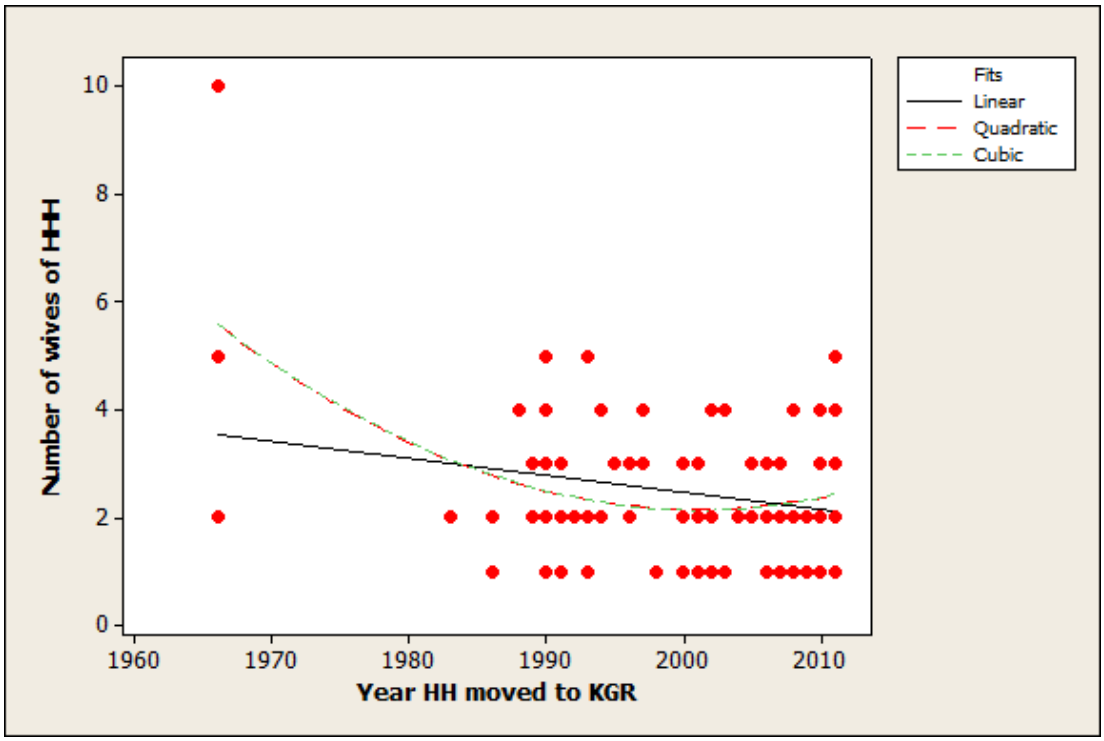


Figure 47 Scattergraph of year household moved to KGR versus number of wives of HHH

Year HH moved to KGR	*N HH*	*1-sample sign*		*1-sample t*	
		Median wives	95% CI	Mean wives	95% CI
2011 (new immigrant)	23	2	(2-3)	2.609	(2.162, 3.055)
<2011 (old settler)	51	2	(2-2)	2.196	(1.920, 2.472)

Table 21 Mean and confidence interval for number of wives of HHH of new immigrants versus old settlers

4.5.4 Household size

Data on household size derived from the March, June and October surveys were investigated for KGR and compared to census data from Chapter 3. Association of household size with that of other variables was also explored.

The distribution of household size is negatively skewed (Figure 48). The mean, median and mode household size were 20.4, 18, and 19; 33.7, 22 and 16; and 28.5, 26.5 and 16 persons for the March, June and October surveys respectively. This means that the average household size of KGR is approximately double that reported by other sources. Awogbade (1983) reported a mean and mode of 12 and 8.25 respectively for semi-nomadic households on the Jos plateau. Iro (2009) reported an average household size of 6.15, lower than the KGR observed values. Ashimolowo reports that 76% of households sampled in Ogun State, southwest Nigeria, had a household size of 4-6 persons (Ashimolowo et al., 2006). Adriansen (2006) observed an average household size of 11 in pastoralist communities of Senegal, and only 16 of the 64 households sampled had more than 20 members. Data from the July 2010 and June 2011 census demonstrated that most households were made up of 6-10 persons (see Chapter 3), which is in agreement with that reported by other authors.

The explanation for the discrepancy between the census and survey data is the different interpretation of a *wuro* (household) between the censuses and surveys. Surveys were concerned with the sampling of all cattle belonging to a household. A *wuro* referred to the extended household or multiple *'ruga'* (homesteads), consisting of a collection of huts belonging to members of the same family as this unit represents a cattle-owning entity headed by the HHH even though individual cattle may belong to different family members. For the censuses, households were defined

as individual *ruga,* consisting of a man, his wife or wives, unmarried children and dependent parents, as this was the unit of interest for the government.

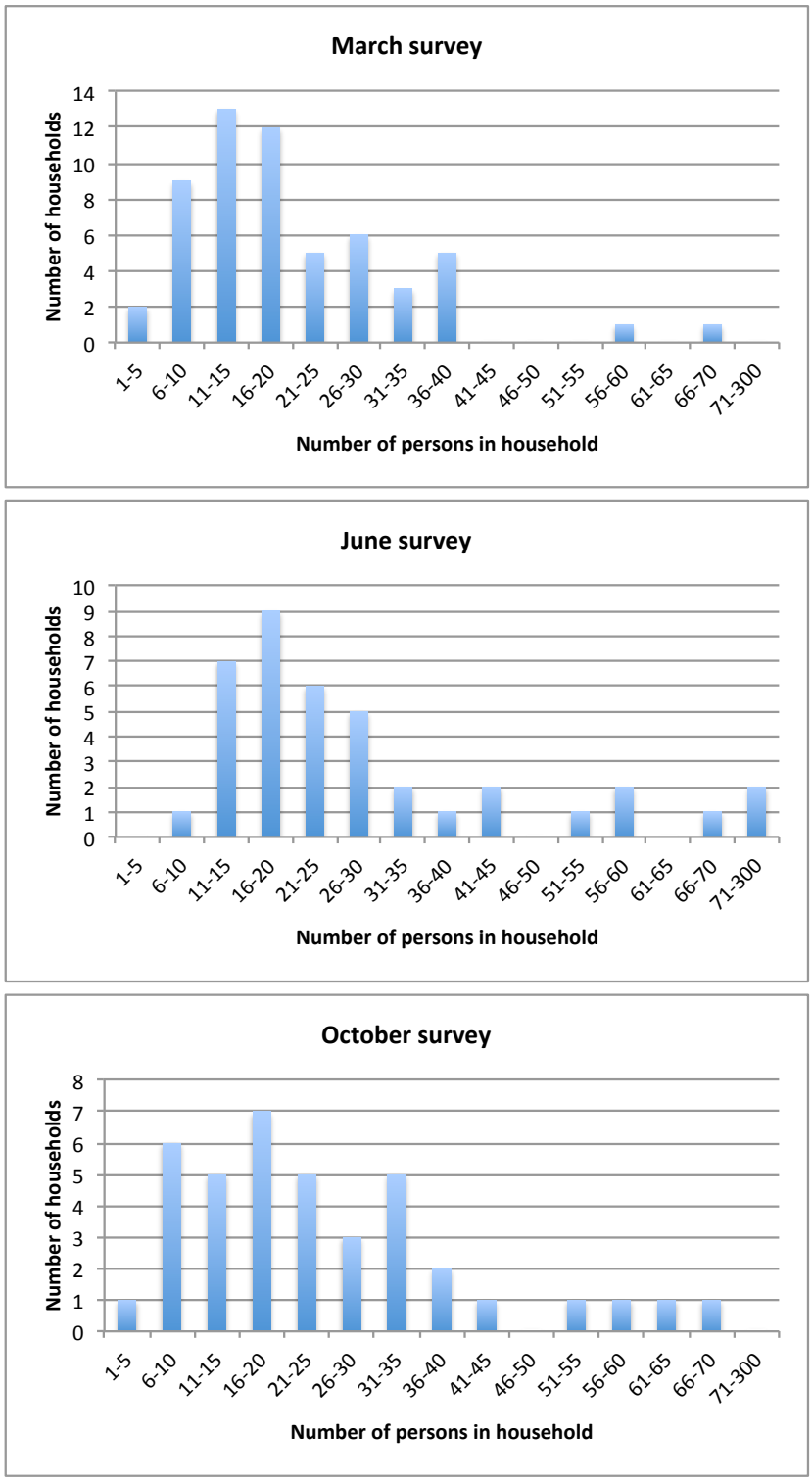


Figure 48 Frequency histogram of household size for the March, June and October surveys

The median household size was found to be statistically different between surveys at the 5-7% level (Kruskal-Wallis test: H= 5.34, DF=2, p=0.069; ANOVA: S=26.16, DF=2, p=0.046). Confidence intervals for median and mean household size were calculated using the sign one-sample sign and one-sample T test respectively for the different surveys, showing that there is minimal overlap in CI between the March and June and March and October surveys (Table 22).

Survey	*N HH*	*1-sample sign*		*1-sample t*	
		Median HH size	95% CI	Mean HH size	95% CI
March	57 38	18.00	(15.00-20.33)	20.35	(17.02-23.68)
June	38	21.50	(17.58-30.00)	34.03	(19.54-48.52)
October	39	22.00	(16.00-28.12)	24.56	(19.59-29.54)

Table 22 Median and mean household size and respective confidence intervals for households sampled in March, June and October

The difference between the median and mean household size of households sampled in March versus those sampled in June and October is likely due to the fact that the March survey did not incorporate the new immigrants which settled in the KGR in May 2011 as a result of post-election violence. Indeed mean and median household size was found to be statistically significantly different between new immigrant households (those than moved into the KGR in 2011) and those that settled in KGR prior to 2011 (ANOVA: DF=1, F=9.34, p=0.003; Kruskal-Wallis: H=7.66, DF=1, p=0.006). Minimal overlap in 95% confidence interval of mean and median confirm that new immigrant households have significantly larger household sizes (Table 23).

Year HH moved to KGR	*N HH*	*1-sample sign*		*1-sample t*	
		Median HH size	95% CI	Mean HH size	95% CI
2011 (new immigrant)	23	31.00	(20.45-55.55)	46.70	(23.10-70.30)
<2011 (old settler)	51	20.00	(16.00-27.00)	22.45	(19.21-25.69)

Table 23 Mean and median household size for households that settled in the KGR in 2011 (new immigrants) or prior to 2011 (old settlers) and respective 95% confidence intervals

The association between household size and TLU/HH for pooled data from March, June and October was investigated and was found to be strongly positively correlated (Pearson correlation coefficient =0.856, p=0.000; Spearman's rank correlation

coefficient=0.503, p=0.000). The association was investigated minus the outlier household with a household size of 277 people (who also owned 1500 cattle). The Pearson and Spearman's rank correlation coefficient were found to be 0.644 (p=0.000) and 0.491 (p=0.000) respectively. This confirms, as discussed previously, that household size and number of livestock owned are interlinked and co-vary.

There is no correlation between household size and TLU/capita for pooled data from March, June and October (Pearson correlation coefficient=-0.002, p=0.980; Speaman's rank correlation coefficient=-0.102, p=0.248). TLU/capita is not proportional to household size since after a threshold of 6 TLU/capita, further increases in household wealth do not lead to further increases in per capita wealth for existing household members.

4.6 Livelihood strategies

Income/production is a direct measure of living standard. The value or magnitude of that income (and its ability to meet household/subsistence needs) is related to its source(s), which can be unique or multiple. Pastoralist households have been diversifying their livelihood strategies to promote resilience to conditions (environmental and social) that push pastoral communities into poverty. Respondent questionnaire data on household income and livelihood strategies from the March, June and October surveys were examined to make inferences about economic wellbeing of individuals and households in the KGR.

4.6.1 Socioeconomic objectives of agro-pastoralist households

An appreciation of the main production objectives of (agro)-pastoralist households is key to understanding household economy and resource management strategies. The five objectives of producers are 1) food security, 2) minimum cash income, 3) risk reduction[4], 5) gaining status within society and 6) group survival (Bonfiglioli, 1993).

Food security is achieved when inputs are sufficient to ensure subsistence of the production unit (household). Inputs include agro-pastoral resources, labour and capital (land and animal). Cash income generated by sale of agricultural or animal

[4] This refers to the risk of losing livestock assets as a result of droughts or other extreme or unique circumstances, which push households into poverty and destitution.

produce meets the immediate household needs for goods that can only be purchased with cash, including clothes, special ingredients for cooking, veterinary drugs and food during the dry season when production does not meet subsistence needs. Agro-pastoral systems are vulnerable to environmental conditions such as drought and social conditions, such as conflict (a unique and extreme circumstance). To reduce risk or vulnerability to poverty, livelihood diversification strategies are employed. A subsistence oriented focus means that material and monetary wealth are poor indicators of social status. The value system is capital based, with social ranking being proportional to livestock ownership. Pastoral societies operate a 'group survival' strategy, which should not be misinterpreted as an egalitarian system, since pastoralist societies are heterogeneous for wealth status. Group survival requires adherence to certain social and economic rules to ensure cohesion and survival of the collective unit, which in part, explains the strong mutual assistance and solidarity networks that exist in pastoral societies (Bonfiglioli, 1993).

4.6.2 Livelihood diversification

KGR pastoralist livelihood diversification should be interpreted within the broader context of rapidly diversifying economies of pastoral peoples in Africa and globally (McCabe et al., 2010). Authors have described an increased uptake of cultivation and off-farm sources of income by pastoral peoples (Fratkin and Roth, 2005, McCabe, 2003, Little, 2003, Hampshire, 2002). Drivers for diversification include a combination of: poverty; risk avoidance strategy; reduced mobility (sedentarisation); government policies and cultural shift that either push or pull households into diversification and normally affect wealthier households (McCabe et al., 2010).

Here the extent to which KGR pastoralists are diversifying their sources of income is examined and inferences made as to how strategies are influenced by wealth status, and how strategies may in themselves impact on wealth status and survival strategies.

4.6.3 Categorisation of agricultural system in KGR

Categorisation as pastoral or agro-pastoral depends on the percentage of income/consumption derived from livestock and livestock-related activities, over 50% for pastoralists and 25-50% for agro-pastoralists (Swift, 1988). Pastoral

communities are not necessarily 'pure' pastoralists, and engage in other livelihood strategies (cropping and off-farm activities). The source of income of KGR households includes a combination of: sale of livestock; livestock products (milk), crop sale, trade (business), salary and daily wage. Data ranking income from different sources enabled the relative contribution of income sources to be estimated.

FGDs revealed that crop and livestock production in KGR is mainly for subsistence. Livestock and crop sales are made only to meet household needs (purchase of herbs, spices and condiments for cooking, clothes, human and veterinary drugs and school fees). The KGR community depends on a cash economy for provision of non-pastoral, non-essential commodities. Social status is based on livestock wealth and serves as a driver to enlarge cattle herds (Chapter 5). Sale of cattle is limited to large cash needs such as for weddings (bride-price) and to meet health costs. The sale of small ruminants, cattle products and crops meet smaller cash needs and spare the cattle herd from sale as previously observed (Adriansen, 2006).

In this section estimated income derived from sale of milk and crops is examined (income from sale of livestock will be discussed in Chapter 5). The different strategies contributing to the household economy of KGR households is described as well as how strategies may differ across blocks, with time following settlement and with livestock wealth (TLU/HH and TLU/capita). New immigrants (those households that moved to KGR in May 2011) are compared to settled KGR households (those than settled in KGR prior to 2011) to examine potential differences in livelihood strategies between the two groups.

4.6.4 Structure of household revenues

The number and percentage of households that engage in the different income/subsistence strategies and household ranking as a contribution to the overall household economy for livestock and agriculture is shown in Table 24. Percentage of milk and crops sold at household level is also calculated.

All households across all surveys engage in livestock keeping and rank livestock keeping as their number one source of income/subsistence in all circumstances (with exception of one household from June 2011, and three from October 2011 who

ranked livestock keeping below crop farming). Between 85-97% of households grow crops, and crop growing was ranked second by nearly all households in terms of contribution to overall household income. In March 2011 approximately half (27) of crop growing households stated they use crops for subsistence only (and hence did not give crops a rank), while half (24) consume as well as sell their agricultural produce. The percentage of crops sold (as compared to consumed) is estimated at 16-22% based on the June and October 2011 survey data.

Revenue	*Number of households (%)*		
	March	June	October
Livestock	**57/57 (100)**	**40/40 (100)**	**39/39 (100)**
Rank 1	57/57 (100)	39/40 (97.5)	36/39 (92.3)
Rank 2	0	1/40 (2.5)	3/39 (7.7)
Average % milk sold/HH	ND	38.5	41.9
Crops	**51/57 (89.5)**	**34/40 (85.0)**	**38/39 (97.0)**
Rank 1	0	2/34 (5.9)	3/38 (7.8)
Rank 2	24/51 (47.1)	32/34 (94.1)	35/38 (92.1)
Average % crops sold/HH	ND	21.6	15.9
Business	22/57 (38.6)	18/40 (45.0)	12/39 (30.8)
Salary	10/57 (17.5)	16/39 (41.0)	12/39 (30.8)
Wage	3/57 (5.3)	7/40 (17.5)	4/39 (10.3)

Table 24 Number of households deriving income from livestock, agriculture, business, salary and wages and rank given for respective contribution of livestock and crops to overall household economy for the March, June and October surveys

Sources of off-farm income are reported by less than 50% of households. Business activities are undertaken in 31-45% of households across the surveys. Salary[5]-based income applies to 18-31% of households and wage[6]-derived/ income to 5-18% of households. Off farm income is ranked 3rd by households and perceived to be less important to the household economy than livestock keeping and crop farming.

Livestock maintained in KGR include cattle, sheep, goats and domestic fowl (chickens, turkeys, guinea fowl, and 2 households also had ducks). A summary of number of households that own each livestock species, the total number of animals owned across all households and the mean, standard deviation and median number of animals per household for the three surveys is shown in Table 25. Since some households owned livestock kept outside of the KGR, ownership was differentiated for cattle kept within and outwith KGR (only for June and October as author only realised the importance of this after having conducted the March survey).

[5] Salary-based income refers to formal employment such as civil servant, teacher, doctor
[6] Wage-derived income refers to casual labour

Species	*Survey*	*Holding*	*N HH (%)*	*Total*	*Mean (s.d)*[2]	*Median*[2]
Cattle	*March*	KGR	57/57 (100)	4730	83.0 (86.6)	50
	June	KGR	39/39 (100)	5110	131.0 (244.9)[1]	65
		Other	15/39 (38)	1124	74.9 (71.2)	45
	Oct	KGR	37/37 (100)	2973	80.4 (114.3)	40
		Other	15/37 (41)	1075	71.7 (61.5)	50
Sheep	*March*	KGR	46/57 (81)	1038	22.6 (26.1)	15
	June	KGR	33/39 (85)	853	25.8 (28.8)	20
	Oct	KGR	32/39 (82)	805	25.2 (17.2)	22
Goats	*March*	KGR	18/58 (69)	538	13.5 (16.0)	10
	June	KGR	27/39 (69)	353	13.1 (8.1)	12
	Oct	KGR	27/39 (69)	580	21.5 (40.8)[1]	13
Chickens	*March*	KGR	55/58 (95)	2613	47.5 (34.1)	40
	June	KGR	37/39 (95)	3607	97.5 (323.9)[1]	31
	Oct	KGR	38/39 (97)	1588	45.7 (30.4)	40
Turkeys	*March*	KGR	7/58 (12)	42	6.0 (4.3)	3
	June	KGR	5/39 (13)	22	4.4 (3.4)	3
	Oct	KGR	2/39 (5)	43	26.2 (21.5)[1]	21.5
Guinea Fowl	*March*	KGR	7/58 (12)	70	10.0 (7.4)	9
	June	KGR	8/39 (21)	51	5.4 (6.2)	5
	Oct	KGR	7/39 (18)	50	10.3 (7.1)	3

Table 25 Comparison of household ownership of cattle, sheep, goats, chickens, turkeys and guinea fowl for the March, June and October surveys. For cattle differentiation is made between cattle kept in KGR ('KGR') or on another holding outside KGR ('other')
[1]high value due to outlier;[2] mean, s.d. and median calculated for livestock owning household of relevance, not all households

4.6.4.1 Livestock and importance to household economy

Fulani do not always keep their animals as a single herd in one area and animals owned by the head of household may be looked after by other family members living away from KGR, as part of transhumance movements or as loans to poor relatives (to enable re-building of their own herd). Cattle ownership is highly complex and responses can vary depending on interpretation of the question (i.e. number of cattle owned where [KGR and/or outside] and by whom [extended and/or immediate family]). In this section, all calculations are based on livestock numbers as reported in the questionnaire (respondents were asked the number of animals in their kraal).

All households in KGR own cattle and keep at least part of their herd solely within the grazing reserve (Table 26) and around 40% of households own cattle kept on holdings outside of KGR. The mean herd size was 80 cattle (the high mean of 131 for the June 2011 is due to one herd size of 1500 cattle). Data are skewed and the median is the more appropriate measure of central tendency. Median cattle herd size across surveys for KGR and other holdings is between 45 and 65.

Over 80% of households in KGR own sheep with mean and median flock size being 23-26 and 15-22 respectively. 70% of households own goats, with average herd size of 14 (mean) and 10-22 (median).

Most households own chickens (95-97%) with a mean flock size of 50 (median 31-40). Under 21% of households own turkeys or guinea fowl, and flock size is small. To examine the contribution of each species to the overall 'capital' (wealth in the form of assets) of households, Tropical Livestock Units (TLU) were calculated (Table 26); whereby 1 TLU = Cattle: 0.7; Sheep/Goats: 0.1; Fowl: 0.01 (FAO).

Total TLU/% TLU per species	*Survey*		
	March	June	Oct
Total TLU cattle	3311.0	4363.8	2833.6
Total TLU sheep	103.8	85.3	80.5
Total TLU goats	53.8	35.3	58.0
Total TLU fowl	27.3	36.8	16.8
Total TLU	**3495.9**	**4521.2**	**2988.9**
%TLU cattle	94.7	96.5	94.8
%TLU sheep	3.0	1.9	2.7
%TLU goats	1.5	0.8	1.9
%TLU fowl	0.8	0.8	0.6

Table 26 Tropical livestock units of cattle, sheep, goats and fowl across all households sampled during March, June and October surveys and percentage contribution to overall TLU per species for each survey

Livestock capital is dominated by cattle ownership with cattle making up 95% of overall TLUs (Table 26). For small ruminants, sheep are approximately twice as important as goats (1.5 and 3.0 TLUs respectively). Domestic fowl account for less than 1% of overall TLU across all surveys.

4.6.4.2 Milk sale and commercialisation

The sale of livestock and livestock products is the most important part of the KGR household economy. Aspects of milk consumption for subsistence, milk sale and milk commercialisation practices are explored in this section. In March 2011, respondents were asked for how many months a year milk production from their herd would be high and for how many months it would be low. They were then asked how this impacted on the proportion of milk available for sale. Households gave similar responses, stating that milk production was high during the wet season (June to January) and low during the dry season (January to May). They described milk production peaking twice during the wet season. Production was described as high at

the beginning of the rainy season (between June and August); fell as the rains peaked in August and increased between October-January as rainfall reduced (Figure 49). Figure 50 shows a peak of precipitation in mm in September and the average rainfall days being highest in August. The average monthly precipitation (mm) and average rainfall days within KGR were extracted from 1950 - 2000. Milk yield was described to drop during peak rainfall; disease pressures may exhibit a negative impact on production or cattle are taken out for grazing for shorter periods during the rains.

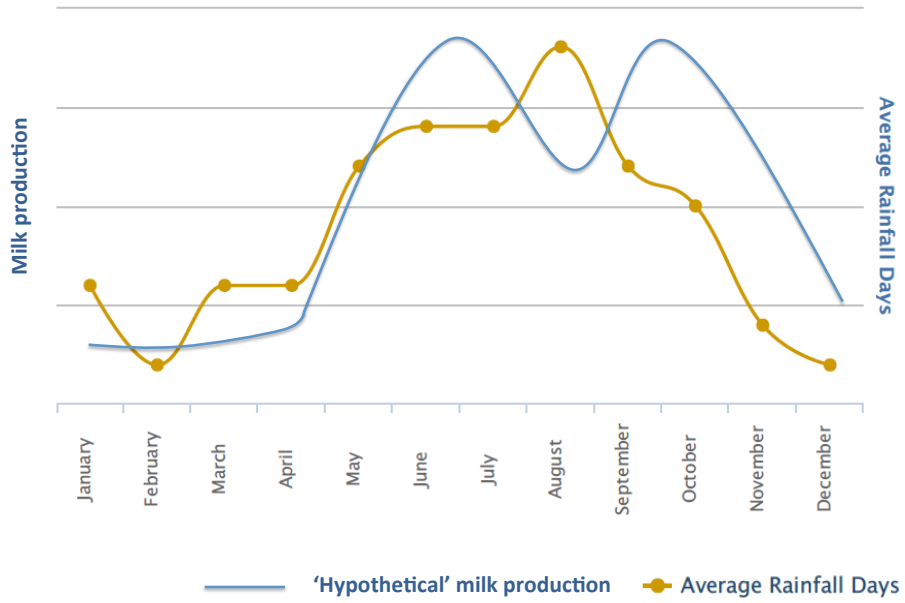


Figure 49 Rainfall days in KGR and seasonal variations of milk production

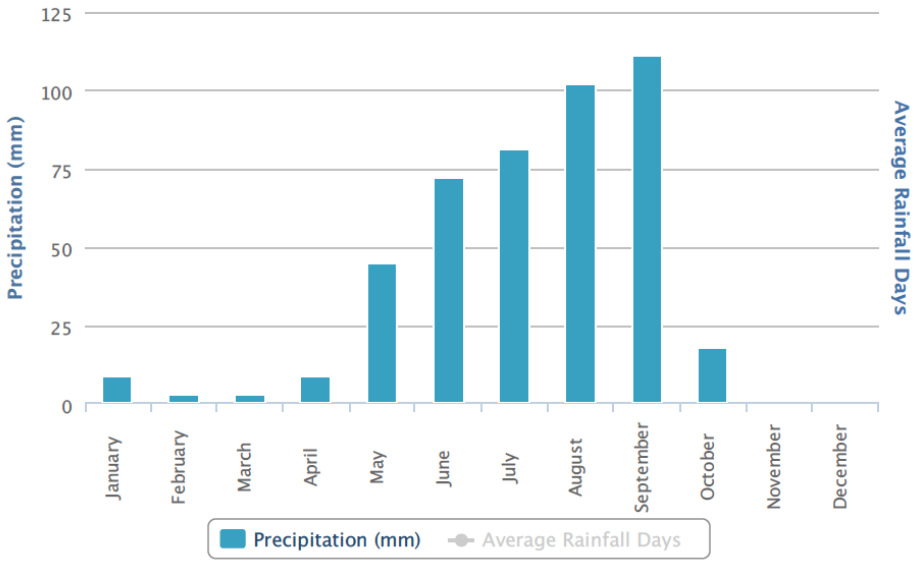


Figure 50 Average precipitation in mm for KGR from January to December

Figure 51 shows that 50% of households sell half of their milk during the wet season, and that only 17% of households consume all and sell none. During the dry season, 83% of households will consume all their milk with only 14% selling their milk; 4% reported not milking their cattle during the dry season.

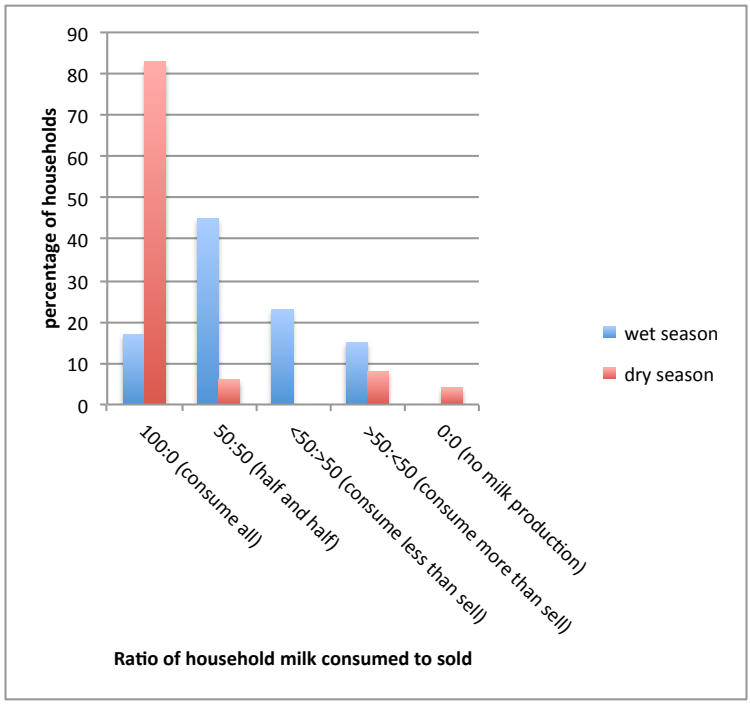


Figure 51 Comparison of the number and percentage of households consuming: selling milk produced at household level during wet and dry season

During the March survey, households were asked to whom the milk was sold and what influenced the decision to sell milk within the household. Respondents described the decision to sell milk as influenced by the amount of milk produced by the herd, which was related to the availability of feed and coincided with the seasons and rains. The priority is to make sure that there is enough milk for consumption of the household, and only if surplus milk is available will milk be sold. Most households stated that they took milk to the central market area to sell directly to the teashops or to people who sell 'nono' (yogurt) in the central market area. Milkopal used to collected milk directly from households and transport it to the central market area. Women mostly sell milk and keep the proceeds to spend on household needs (cooking ingredients and on their children). One person stated that some milk taken to the market area is sold to people who then take it to Kano to sell.

The correlation between a 'proxy' for quantity of milk sold at household level and TLU/capita and TLU/household was investigated. To estimate proxy milk volume produced at household level the percentage of all milk produced at household level sold by the household was multiplied by the cattle herd size. This assumes that milk yield per animal and number of milking females per herd across households is constant. As herd composition in terms of proportion of productive female animals is fairly constant across herds (see Chapter 5) this was felt to be acceptable, although there may be variations in milk yield between herds are unaccounted for by the proxy. The Pearson's and Spearman's rank correlation coefficients were found to be 0.874 (p=0.000) and 0.755 (p=0.000) indicating that there is a strong positive correlation between the TLU/HHH and milk volume sold at household level, and by inference between TLU/HHH and revenues derived from sale of milk.

Correlation between TLU/capita and proxy quantity of milk sold was found to be weaker but still positive (Pearson correlation coefficient=0.393, p=0.000; Spearman's rank correlation coefficient=0.489, p=0.000).

The reason for the positive correlation is that households with higher TLU have a larger cattle herd size and by default more milk producing females, and hence produce more milk for sale and are therefore able to derive more income from milk production at household level. Correlation with TLU/capita and volume of milk sold at household level is weaker because households with larger cattle herds also have a larger household size and hence even though more milk is produced as compared to milk production of households with smaller herds, a larger number of mouths to feed at household level also means that a larger quantity of milk has to go towards household subsistence. This is due to the co-variance and proportionality between household size and herd size, as previously discussed.

Mean and median milk sale at household level was not found to be statistically significantly different across blocks (one-way ANOVA: DF=5, F=1.38 and p=0.242; Kruskal-Wallis: H=5.78, DF=5, p=3.29). Differences in mean and median milk sales were found to be statistically different between new immigrant (HH that moved in 2011) versus old settler (HH that moved before 2011) households, with new immigrant households having a higher mean and median proxy magnitude milk sale

than old settlers (One-way ANOVA: DF=1, F=18.75, p=0.000; Kruskal-Wallis: H=13.58, DF=1, p=0.000). This is due to new immigrants households have a larger herd size than old settler households and hence produce more milk.

4.6.4.3 Crop farming and importance to household economy

According to the KGT project officer Project Office (State Government), regulations originally stipulated that households settling in KGR were allocated 10 hectares, with a proviso that 4 hectares should be dedicated to crop farming. This is no longer enforced and the number of hectares farmed varies between households.

Households were questioned in March 2011 on the actual number of hectares farmed. The number of hectares farmed was compared across blocks (Figure 53). Most households farmed two hectares (Figure 52). Block 1 contained households that farmed the greatest number of hectares and 6 of the 7 households who cultivated 10 hectares were situated in this block. One household from Block 1 farmed 50 hectares. Blocks 2, 3 and 4 cultivated a median of 2-3 hectares each. Block 3 had one household which cultivated 20 hectares.

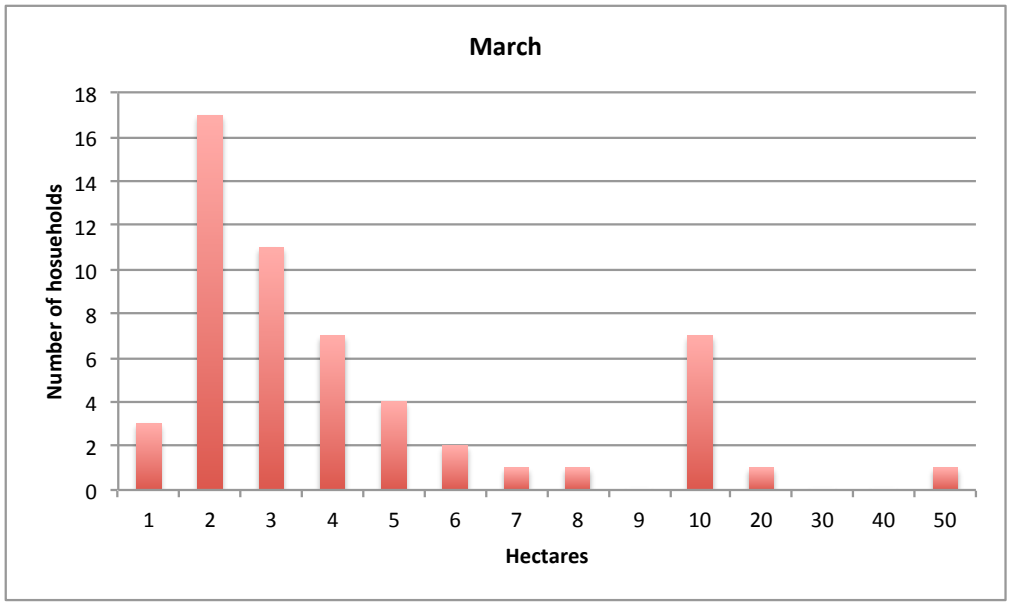


Figure 52 Frequency of hectares farmed by households, March survey

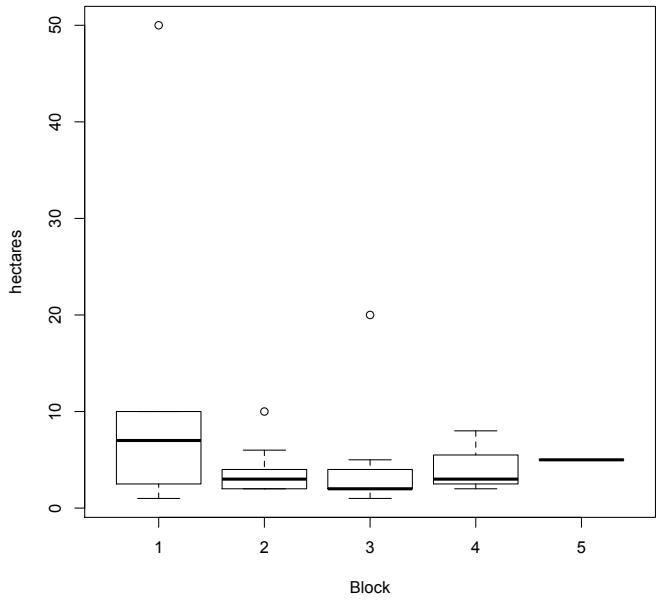


Figure 53 Hectares cultivated per household for each block, March survey

Association between block and hectares cultivated was not statistically significant (ANOVA: DF=4, F=1.49, p=0.220; Kruskal-Wallis: H=4.45, DF=4, p=0.348). Mean and median hectares for the blocks sampled in March were found to have overlapping confidence intervals (Table 27), although the overlap in CI between Block 1 and 2 is the smallest, demonstrating that there is some difference between these two blocks. Block 1 has households with the highest livestock wealth and also farms the most hectares of any block, re-emphasising the wealth supremacy of the inhabitants in this block over those residents in over blocks.

Block	*N HH*	*1-sample sign*		*1-sample t*	
		Median hectares	95% CI	Mean hectares	95% CI
1	15	7.00	(2.37-10.00)	8.87	(2.23, 15.51)
2	24	3.00	(2.00-4.00)	3.50	(2.70, 4.30)
3	11	2.00	(2.00-4.01)	4.27	(0.68, 7.87)
4	4	3.00	(2.00-8.00)	4.00	(-0.31, 8.31)
5	1			5.00	
Total	55				

Table 27 Mean and median hectares and respective confidence intervals across Blocks 1 to 6

The hypothesis that hectares farmed may increase with time lived in KGR was explored. The number of hectares farmed was not found to be correlated with the year a household moved to KGR (Pearson correlation coefficient=0.028, p=0.001).

There was a moderate positive correlation between number of hectares farmed and HH size (Pearson's correlation coefficient=0.396, p=0.003; Spearman's rank correlation coefficient=0.432, p=0.001) and between number of hectares farmed and TLU per household (Pearson's correlation coefficient=0.431, p=0.001; Spearman's rank correlation coefficient=0.444, p=0.001). There was a weak positive correlation between TLU/capita and hectares farmed (Pearson's correlation coefficient=0.150, p=0.275; Spearman's rank correlation coefficient=0.270, p=0.046).

Larger households being able to cultivate more land is logical as labour for ploughing, seeding, weeding, harvesting is derived from the household unit. Hence the more people live in a household, the more manpower is available to cultivate crops. Contrary to the hypothesis that households owning fewer, livestock may be diversifying their livelihoods by engaging in larger scale crop farming, it is actually the households with the most livestock assets that farm the most crops. This again is related to the fact that number of livestock owned and household size are intrinsically linked, proportional and co-vary, as the ability to look after large livestock herds also depends on the availability of manpower. This explains the absence of a correlation between TLU/capita and hectares farmed.

The types of crops that were farmed were determined from the March 2011 survey. Respondents were asked to list crops grown by their household and to rank the importance of each crop in terms of subsistence and/or cash value. The 'average rank' for each crop variety was calculated based on the mean rank given each crop variety. Ranking was attributed from 1 (most important) to n+1 (least important). For example, in a household that cultivated maize, yam, beans and rice, and in which maize was most important, yam and beans of equal second importance and rice of least importance, ranks of 1, 2, 2 and 4 were given. Households that did not cultivate a specific crop were excluded from the average rank calculation for that crop.

The percentage of households that cultivate maize, sorghum, sweet potato, yam, cocoa yam, beans, rice, cassava, groundnut and millet is shown in Figure 54. The most important crop for household economy in KGR is maize, followed by sorghum. Other crops were ranked 3rd or more and are cultivated by 70% or less of households.

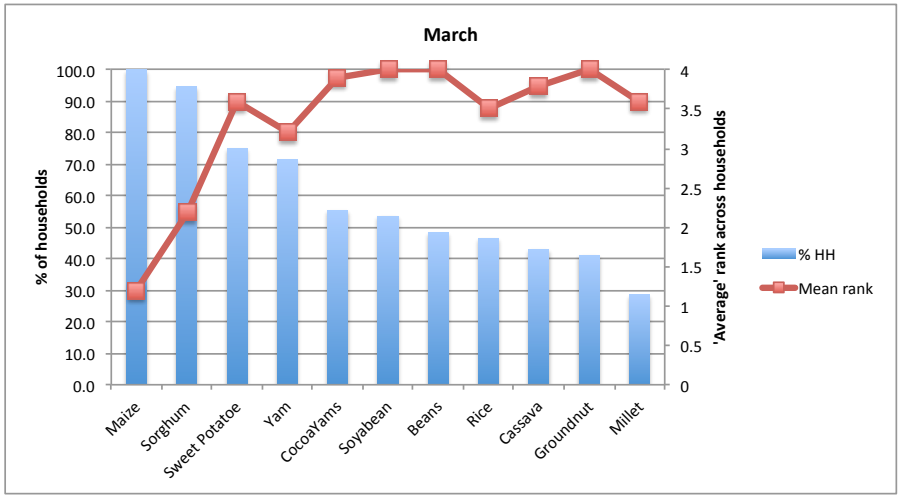


Figure 54 Percentage of households sampled in March that grow each crop, and the 'average' rank given

Households were interviewed about methods used for ploughing their fields. 17/57 households used animal traction (29.8%), 56 households used at least some family labour and 38 households hired some labour. The 17 households that used plough oxen stated that animal traction accounted for 10-60% of all ploughing, with most households stating that animal traction fulfilled 30% of all ploughing needs. 13 households used only family labour for ploughing. The remaining households used combinations of family labour +/- hired labour +/- animal traction. Households that hired labour stated that this accounted for between 20-80% of all ploughing needs.

The reason most households in KGR have to rely on a majority of family labour for ploughing is illustrated through a KII with Damina Abdulahi: *"Outside the KGR you are around other non-Fulani settlers and you have the privilege of hiring labour to work on your farm. Here in the KGR we have the constraint of not having enough labourers as people around are Fulanis whose expertise is animals, not farming. Other tribes do not come in here"*.

Proportion of ploughing undertaken through animal traction was positively correlated with TLU/HHH (Pearson correlation coefficient =0.446, p=0.001). Correlation of number of hectares ploughed through animal traction (calculated by multiplying number of hectares farmed by percentage of land ploughed through animal traction) was also found to be positive (Pearson correlation coefficient=0.453, p=0.000).

Households with larger herd sizes may be more likely to own plough oxen and use these animals for ploughing. KII revealed, however, that not many households own plough oxen, and that those that do generally loan their animals for use by other households. The proportion of ploughing undertaken using animal traction was positively correlated with number of hectares owned. As hectares are positively correlated with TLU, this infers that households with large herds cultivate more land and have to resort to using animal traction to facilitate ploughing of larger parcels of land, which are too big to be ploughed through manual labour alone.

The number of hectares ploughed through hired labour was estimated by calculating the number of hectares owned by the proportion of land reported ploughed through the use of hired labour. Number of hectares ploughed through hired labour was positively correlated with TLU/HH (Pearson correlation coefficient=0.424, p=0.001). TLU reflects livestock wealth, and wealthier households are more likely to be able to afford to pay for labour and therefore do less of the ploughing themselves. They also have more land to plough due to the correlation between hectares and TLU/HH, hence not all ploughing can be achieved by the available household members.

4.6.4.4 Crop production for subsistence, sale and fodder

Households were interviewd during March 2011 on the percentage of their overall crop production that are consumed within the household, fed to livestock and/or sold for cash. 54 households provided answers. Percentages were multiplied by the number of hectares farmed to calculate a proxy for overall quantity of crops fed to livestock, consumed within the household or sold for cash. For example, a household with 10 hectares and reporting to feed 20% of crops grown to livestock, feed 70% of crops to household members and sell the remaining 10% would in fact feed 2 hectares worth of crops to cattle, feed 7 hectares to household members and sell the remaining 1 hectare. This is an over simplification since different crops have different economic values, but detailed analysis of the value of crops sold/consumed/fed to livestock was beyond the scope of this theis. It was emphasised that only crops grown specifically for use as cattle fodder were of interest. All households within the KGR give cattle and small ruminants access to crop stubble, especially maize, after harvest.

All households in the KGR grow crops, and the majority of crops grown are for consumption within the household (subsistence). Just over half (57% of households) sell the crops they produce, and those that sell crops sell less than 50% of their overall crop production. Only 11 out of 54 households (20.4%) reported growing crops for feeding to livestock. 10 of those households were from Block 1, and only 1 household from Block 3. Only 5-20% of all crops grown are fed to livestock for those households that grow livestock fodder.

The association between block and the proportion of crops fed to livestock was investigated. The p-values for the one-way ANOVA (DF=4, F=7.44 p=0.00) and Kruskal-Wallis (H=14.44, DF=4, p=0.006) indicate that there is sufficient evidence not all means and medians are equal when alpha is set at 0.05. The means and medians of proportions of crops fed to livestock and their respective confidence intervals for each individual block were also calculated, demonstrating that there is no overlap in confidence intervals between Block 1 and other blocks (Table 28).

Block	*N HH*	*1-sample sign*		*1-sample t*	
		Median crops fed	95% CI	Mean crops fed	95% CI
1	14	5	0-10	6.43	(2.60-10.26)
2	24	0	0	0	0
3	11	0	0	0.909	(0-2.935)
4	4	0	0	0	0
5	1	0	0	0	0
Total	54				

Table 28 Mean and median proportion of crops fed to livestock and respective confidence intervals for the different blocks

There is a moderate positive correlation between the quantity of crops fed to livestock and TLU/HH (Pearson correlation coefficient=0.433, p=0.001). As herd size increases, so does the quantity of crops produced fed to livestock. Large herds require more grazing, and due to limitations in rangeland within the KGR, growing crops to supplement feeding to cattle is a good approach.

Household uptake of growing fodder for animals, however, is not consistent across all households with large herd sizes from all blocks.

The reason the vast majority of households growing fodder are from Block 1 was estabilised during a KII. In the 1980s, the Sub-humid zone project commissioned by the World Bank and NLPD (National Livestock Development Project, Federal Government of Nigeria) (see 3.1.4.2.4 ILCA Sub-humid Zone Programme) was undertaken in the KGR. One of the KI interviewed, Damina Abdulahi, was among the first settlers of 1978 and experienced the project first hand: *"I was happy to work for the World Bank project as the animals have benefitted from such projects. They taught us the importance of growing fodder for our animals. Originally my family and I lived near the road but the World Bank project told us to move inwards on the understanding that they would make schools available. So we moved to what is called Block 1 today to take advantage of those amenities".*

When asked as to why only households from Block 1 grew livestock fodder Abdulahi re-affirmed that Block 1 contains a large proportion of the elite, long-time settlers of the KGR and that this Block had the greatest exposure to the fodder-bank project. He comneted that the advice they received from researchers and government officials on the importance to grow fodder for animals has lived on but has not been disseminated to other blocks. Abdulahi emphasized that some of the Block 1 inhabitants, namely the earliest settlers like himself who moved in to KGR in the 1980s, are more sedentary than the inhabitants of other blocks, taking a smaller proportion of the herd away for transhumance during the dry season. They need to supplement grazing with fodder during the dry season is greater for them, as without this supplementary feeding the poor quality of dry season grasses within the KGR would not be able to sustain the animals. He added: *"Right from the beginning of time, not all Fulani were motivated to have very large herds. When the place was earmarked as a grazing reserve, some household heads came and looked at the place and were convinced that moving to the KGR was worthy. When the households decided to move here, they had to move with their dependents, and some of the dependents did not have herds of their own. This stimulated some of them to go into crop farming as a way of reducing the pressures on the needs from the household."*

This suggests that the first and earliest settlers in the KGR were motivated to engage in crop farming. Block 1 households have the highest mean and median hectares of

farmed land of any block (Table 27). Comparing median and mean proportion of crops sold shows that despite farming the most land, Block 1 households sell the lowest proportion of their crops of any block (Table 29).

Block	*N HH*	*1-sample sign*		*1-sample t*	
		Median % crops sold	95% CI	Mean % crops sold	95% CI
1	13	0	(0, 10)	5.62	(0-11.85)
2	24	22.5	(0, 31.73)	18.96	(10.87, 27.05)
3	11	20	(9, 51.40)	27.91	(10.17, 45.65)
4	4	17.5	(0-33)	17	(0, 43.91)
5	1				
Total	53				

Table 29 Mean and median proportion of crops produced by households which are sold and respective confidence intervals for each block

Block 1 households also some of the largest household sizes, and hence retain most of the crops produced for feeding of these large families. Taking into consideration the actual quantity of crops sold (number of hectares cultivated multiplied by percentage of crops sold) rather than solely the proportion of crops sold, there is a moderate positive linear correlation between crop sale and household size (Pearson correlation coefficient=0.369, p=0.002). Household size and herd size co-vary and there is a positive correlation coefficient between TLU/HH and crop sale (Pearson correlation coefficient=0.345, p=0.009). There is no correlation, between TLU/capita and the 'proxy' quantity of crops sold (Pearson correlation coefficient=0.117, p=0.409), due to proportionality between household size and livestock ownership.

The quantity of crops fed to people within the household is positively correlated with household size (Pearson correlation coefficient=0.339, p=0.010). Large households with large herds grow more hectares of crops, especially early settlers from Block 1. Since they grow more crops they derive more income from crop sale than the smaller households that grow fewer crops. There is no correlation between TLU/capita and proxy for crop sale. After a certain threshold, further increases in TLU/HH do not result in increase in TLU/capita due to the proportionality between household size and livestock capital. Households with more people do grow and sell more crops, but when this is divided between the number of people per household, the quantity of

crops sold per person is not higher for a household with many householders as compared to a household with few householders.

4.6.5 Off-farm sources of income

Uptake of off-farm sources of income was determined for each block. Households were asked if any of their household members engaged in business activities, salaried work or casual labour paid in wages, to describe the activity. The percentage of households engaging in such work across the 3 surveys is shown in Figure 55.

A higher percentage of Block 1 households owned a business but business activities were undertaken in all blocks. Salaried work was highest in Blocks 2 and 3 (not March survey). The number of households engaging in casual labour was variable but overall fewer households engaged in this activity.

Businesses owned included a variety of shops situated in the market centre of Ladduga, including drug shops, tea shops, a phone charging shop, a motorcycle repair shop, a general provision store, a maize grinding service and a tailor shop. Numerous respondents reported involvement in cattle trading and operating a motorbike taxi service. One respondent is a registered contractor of an agro-services company 'Salisu & sons', involved in 'selling and supplies'. Two respondents had a house building enterprise and a carpentry business.

Salaried employment included teaching, bus driving, paramedic, health workers, computer technician, policeman, and various other civil servant positions. Casual labour activities consisted of building and agriculture related activities such as weeding, ridging, planting, sowing and ploughing.

The mean and median household size, TLU/HH, TLU/capita were compared for pooled data of households sampled in March, June and October that have and do not have households members engage in salaried work, business and casual labour (Table 30). The data suggests that larger households with greater livestock wealth are more engaged in salaried-work or business, whereas it is the smaller and poorer households in terms of household wealth that engage in casual labour (waged-work). This is interesting because it goes against the hypothesis that households with smaller herds may be diversifying their sources of income and engaging more in off-

farm activities. The data suggest that it is the households with the most livestock and the most people that undertake business or salaried work and that smaller households with small herds are engaging more in casual labour to supplement income.

'Wealthy' households in the KGR own more livestock, grow more crops and have household members engaged in business or salaried work. Poor households are livestock and land poor and tend to supplement their income with wages rather than the more lucrative business or salaried-work as sources of off-farm income.

Since herd size is correlated with household size, there is a proportionality between the number of livestock owned by a household, the number of people this household contains, the hectares of land farmed and also the presence of persons that undertake some form of off-farm work. This proportionality means that there is no association between TLU/capita and uptake of salaried-work, business or waged-work, as demonstrated by the overlapping confidence intervals in mean and median TLU/capita for households that have and do not have household members engaged in off-farm activities (Table 30). This is due to the threshold in per capita wealth with further increases in household wealth as illustrated in Figure 39.

There is an interesting contrast between the presence/absence of persons at household which engage in salaried-work and business versus those that undertake casual labour: casual labour is undertaken in smaller households with lower TLU/HH and household size, whereas salaried work and business is undertaken by larger households with higher TLU/HH and household size.

A higher percentage of households in the 'poor to medium wealth' categories, as defined by TLU/capita, engage in business activities (Figure 56). The level of 50 percent for households categorised as destitute from the March survey must be interpreted with caution, as there are very few households in this category. The mean rank given in terms of contribution of business to the overall household income shows that households in the medium rank category as defined by TLU/capita engage more in business. 'Wealthy' households do not engage in business at all.

The salary pattern is similar to that for business activities, a larger percentage of poor households (defined by TLU/capita) engage in salaried-work (Figure 57).

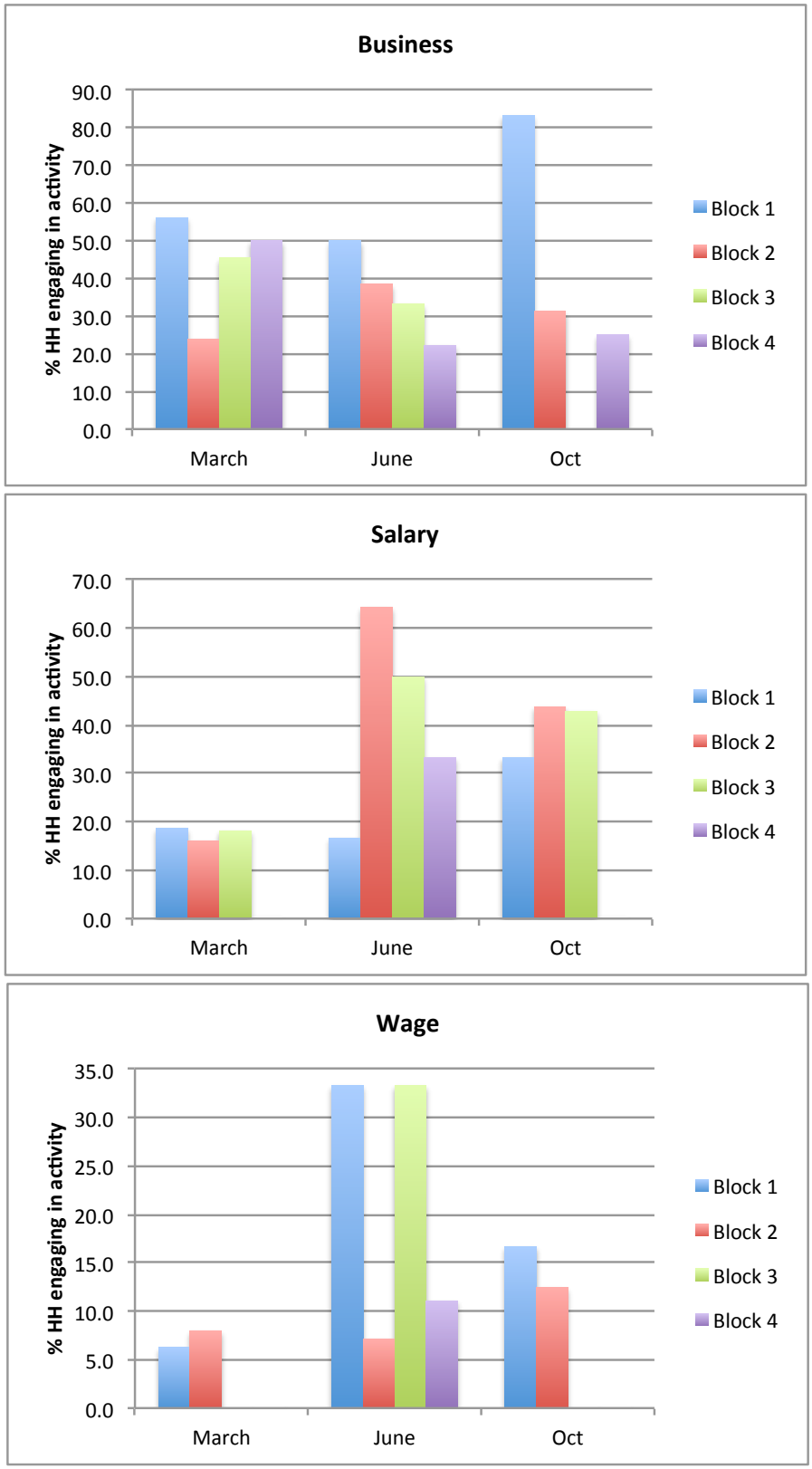


Figure 55 Percentage of households engaging in business, salaried-work or casual labour

Off-farm income		*YES- salary*	*NO- salary*	*YES-business*	*NO-business*	*YES-wage*	*NO-wage*
N HH		39	94	52	82	15	119
1-sample sign	Median HH size	**26**	18	**24**	17.5	**23**	19
	95% CI	(18.9, 31.1)	(16, 20)	(19, 27.5)	(15.7, 20)	(10, 27.3)	(17, 21.7)
1-sample t	Mean HH size	**34.1**	21.9	**30.2**	22.5	19.3	**26.2**
	95% CI	(20.3, 47.9)	(18.8, 25.0)	(19.8, 40.6)	(18.9, 26.0)	(13.5, 25.1)	(21.2, 31.3)
1-sample sign	Median TLU/HH	**54.3**	45.8	**54.3**	43.1	32	**50.6**
	95% CI	(35.4, 84.9)	(34.1, 58.4)	(37.2, 78.0)	(30.1, 58.8)	(20.6, 62.9)	(38.0, 62.8)
1-sample t	Mean TLU/HH	**112.8**	67	**98.7**	71.2	57.5	**85**
	95% CI	(53.2, 172.4)	(52.2, 81.8)	(54.0, 143.4)	(52.9, 89.4)	(27.0, 88.0)	(62.2, 107.8)
1-sample sign	Median TLU/capita	2.475	**2.646**	**2.766**	2.574	**2.817**	2.64
	95% CI	(1.738, 3.893)	(2.155, 3.087)	(2.150, 3.330)	(2.023, 3.100)	(1.084, 5.261)	(2.168, 3.053)
1-sample t	Mean TLU/capita	**3.136**	3.023	3.09	**3.131**	**3.595**	3.054
	95% CI	(2.437, 3.835)	(2.544, 3.502)	(2.501, 3.678)	(2.575, 3.687)	(1.748, 5.443)	(2.649, 3.459)

Table 30 Comparison of mean and median HH size, TLU/HH and TLU/capita and respective confidence intervals for households that have versus those that do not have household members which engage in off-farm sources of income (salary, business and wage)

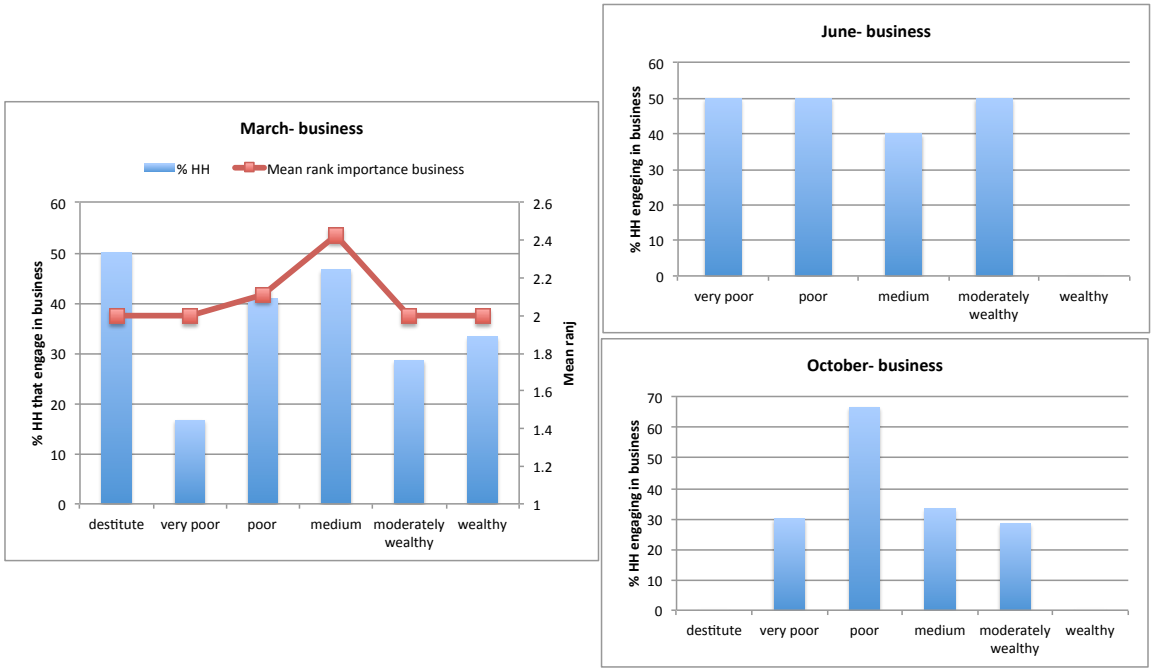


Figure 56 Percentage number of HH that engage in business activities across wealth categories (TLU/capita) and mean ranked importance of business to HH income (March survey, left panel); Percentage number of households engaged in business across wealth categories (TLU/capita) (June and October surveys, right panel)

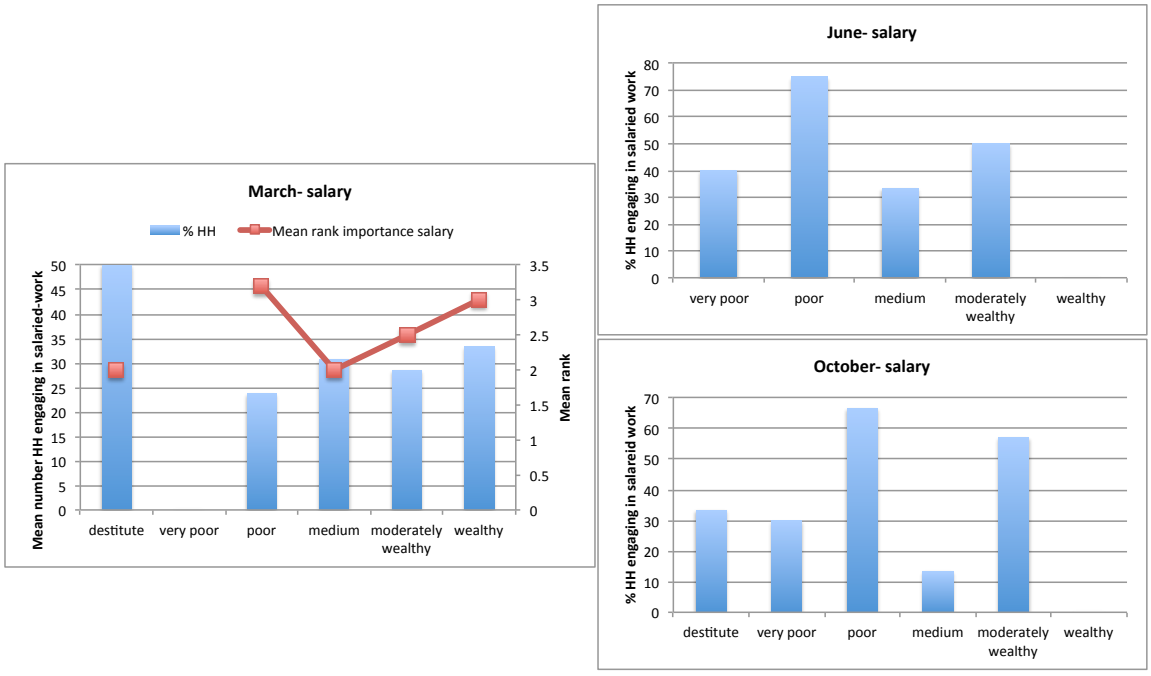


Figure 57 Percentage number of HH that engage in salaried-work across wealth categories and mean ranked importance of salary to HH income (March survey, left panel); Percentage number of households engaged in salaried-work across wealth categories (June and October surveys, right panel)

Uptake of casual labour by households is not related to TLU/capita. Individuals from households in any wealth category receive a wage to supplement income (Figure 58).

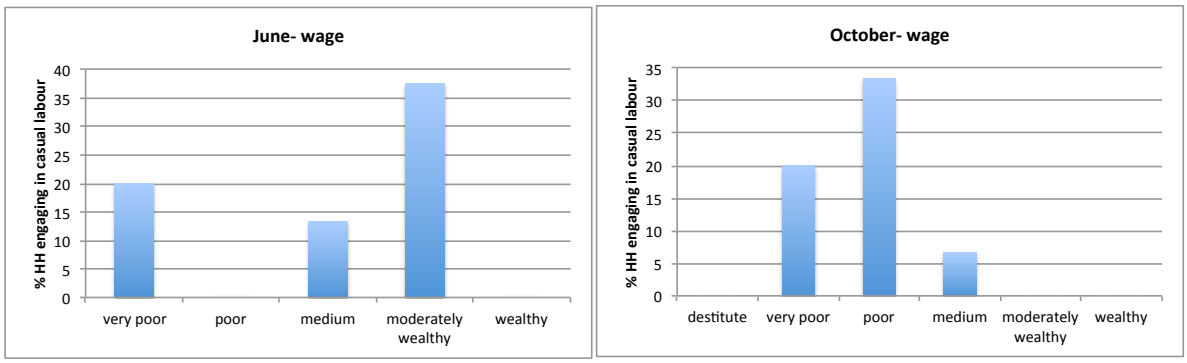


Figure 58 Comparison of percentage number of households engaged in casual-labour and who receive a wage across wealth categories (June and October surveys)

Due to the curvilinear relationship between TLU/HH and TLU/capita, households with large herd sizes may also have large household sizes and will attain a low TLU/capita score. The reverse is true for households with small herd sizes, as these may contain fewer household members and will score higher in terms of TLU/capita. The wealthiest households in terms of TLU/capita are those with the largest herd size and the lowest HH size. The poorest households are those with the smallest herd size and largest HH size. Figure 56 and Figure 57 show that when TLU/capita is high, households apply human resources to pastoralist activities and do not 'diversify', possibly as household needs are fully met by income from their livestock.

Adoption of business livelihood strategies by households with a low TLU/capita score means that income derived from livestock is supplemented, and suggests that the actual wealth status of these households may be higher than that indicated by the TLU/capita alone and that the overall household budget will be higher than that obtained from livestock resources alone. A compound wealth indicator, taking into consideration livestock capital and income from agriculture or off-farm activities may therefore be more appropriate for KGR.

A study of pastoralist communities of Kenya by Little et al. (2008) reported that the poorest categories of households (with less than 1.0 TLU per capita) had the most diversified sources of income. Households with more than 4.5 TLU per capita were reported to focus heavily on pastoral based activities and avoid diversification.

4.6.5.1 Mutual assistance

Strong networks for solidarity, assistance, and cooperation exist among Fulani pastoralists, both at the level of kinship group and the clan (Bonfiglioli, 1993). In traditional pastoralist communities, cooperation occurs at the level of the encampment since this is the most convenient unit for organising management of cattle. In agro-pastoralist communities, mutual aid is exercised at the level of the domestic unit. Traditionally, when pastoralists existed outside of the cash economy, exchange of goods consisted of exchange, gifting or loaning of livestock (mostly cattle). Circulation of animals is still practiced; respondents reported that for Zakat (Islam religious act of donating goods or money to 'needy' community members, the amount proportional to the wealth of the donor), the KGR community would donate cattle to poor community members (see Chapter 5). Families will receive money from family members to complement their income, and will donate money if their financial situation permits it and the situation of a family member warrants it.

Households were asked if they received money from family members that do not live in their household. The percentage of households receiving money varied from 10-65% (Figure 59), with no consistency across the surveys. This indicates that receipt of money depends on factors external to those of the KGR i.e. having family members outside of KGR who can afford to send money. Most households receiving this income supplement would do so once or twice yearly.

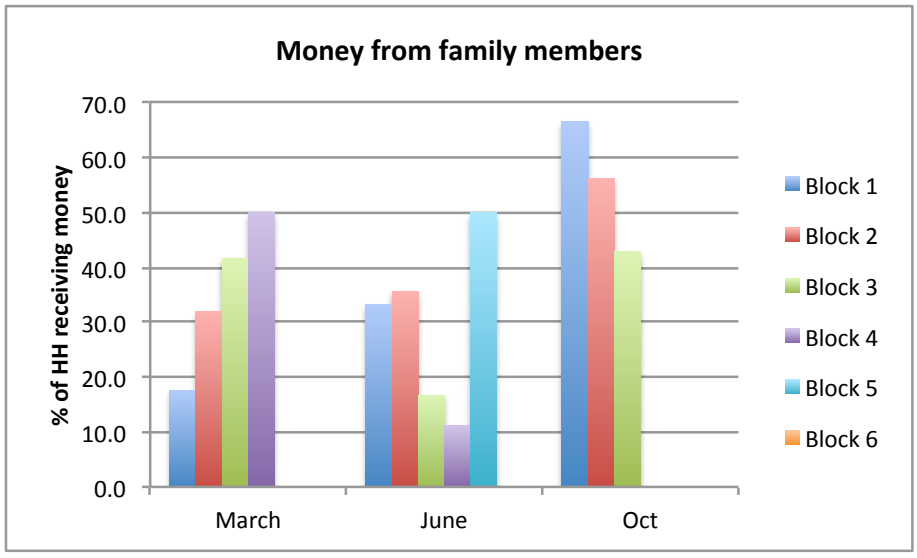


Figure 59 Percentage of households receiving money from non-household family members

The mean and median household size, TLU per household and TLU per capita for pooled data from March, June and October was compared for households that receive and do not receive money from family members living outside KGR. Although the confidence intervals both for mean and median overlap suggesting that there is no significant difference between the HH size, TLU/HH and TLU/capita that receive money versus those that do not, the median and mean, especially for TLU/HH and TLU/capita, is higher for households that do not receive money (Table 31). This was confirmed during FGDs, as KGR members confirmed that money is usually sent to poorer households with smaller livestock herds rather than those with larger herds and greater wealth who can support themselves on revenue from their herds alone.

Receive money from family members outside of KGR		*Yes*	*No*
N HH		45	89
1-sample sign	*Median HH size*	**21.0**	17.5
	95% CI	(17.5, 25.5)	(16, 21)
1-sample t	*Mean HH size*	24.5	**25.9**
	95% CI	(20.7, 28.4)	(19.3, 32.5)
1-sample sign	*Median TLU/HH*	44.5	**52.3**
	95% CI	(29.3, 58)	(36.7, 68.8)
1-sample t	*Mean TLU/HH*	68.5	**88.9**
	95% CI	(45.3, 91.7)	(60.0, 117.8)
1-sample sign	*Median TLU/capita*	2.201	**2.646**
	95% CI	(1.457, 3.394)	(2.110, 3.089)
1-sample t	*Mean TLU/capita*	2.991	**2.940**
	95% CI	(2.093, 3.889)	(2.335, 3.544)

Table 31 Mean and median HH size and TLU for households that receive and do not receive money from family members outside of KGR and respective confidence intervals

4.7 Conclusion

Wealth status, size, composition, and livelihood strategies of KGR households were explored. Proportionality was observed between the number of cattle owned and number of persons in the household. After a certain threshold in TLU/capita, defined as 6 TLU/capita for the KGR, increases in TLU/HH will not result in further increases in TLU/capita. Members of larger households with larger herd sizes may be individually poorer than those who live in small households with few cattle. TLU/HH and TLU/capita were not constant across Blocks. Block 1 and 4 were 'wealthier' than Block 2.

Most households are 'compound households' comprised of a household head, his wives and his children, and the wives and children of his sons or brothers. Livestock rearing is the main source of income, but diversification into agriculture, business,

salaried work or casual labour activities is widely practiced. Households with superior livestock wealth (TLU/HH) are also engaged in large-scale crop farming, but production is predominantly for subsistence (as these households are also larger in size). Households from Block 1 grow crops for fodder, a practice that is almost unique to this block. Income derived from crop sale and milk sale is correlated with TLU/HH and household size, but not with TLU/capita. Number of wives of HHH is correlated with both TLU/HH and TLU/capita.

Households with lower TLU per capita tend to engage more in off-farm activities such as business and salaried work, demonstrating that poorer households are diversifying their household economy whilst the households with a high TLU/capita are retaining their pastoralism focus. Households with higher TLU/HH and household size are more engaged in salaried-work and business whereas households with lower TLU/HH and household are involved in waged-work (casual labour).

The number of possessions and buildings are not reliable proxy indicators of wealth or poverty defined in terms of TLU in the KGR context. Proxies based on livestock wealth, such as the TLU per capita or TLU per household may not reflect global household income, as livelihood diversification is practiced and contributes to household economy and households with lower TLU/capita and TLU/HH also tend to receive more money from family members living outside the KGR.

5 Chapter 5 Livestock production

5.1 Transhumance

Prior to the first survey conducted in the KGR it was assumed that the population in KGR was sedentary since the primary objective of grazing reserves was to reduce pastoralist movements and sedentarise these communities. The survey undertaken in the dry season (March 2011) showed that most households had taken some or all of their cattle out of the KGR due to the lack of grazing. Questionnaires and focus group discussions undertaken after March 2011, in June and October were adapted accordingly to capture data on transhumant habits.

The section below explores the transhumance in terms of number of households practising transhumance (both during the dry and wet seasons), and the proportion of each herd taken out of the KGR (i.e. which animals travel and which animals remain, if any). The household factors that influence the decision to stay in the KGR (block of origin, years since settlement in the KGR, wealth status and size of herd) were examined. Information is presented on the timing and duration of the wet and dry season transhumance, and choice of destination of transhumant households, the reasons for leaving KGR and who makes the trip to accompany the cattle.

5.1.1 Materials and methods

The results draw upon data from surveys undertaken in March, June and October 2011. Descriptive statistics have been used to calculate percentages and frequency histograms and bar charts are included to summarise data.

5.1.2 How many?

The number and percentage of households undertaking transhumance for each block and overall in KGR are summarised in Table 32. For the June and October surveys further subdivision into wet and dry, dry only and wet only transhumance is made. Since households were asked if they had practiced transhumance in the last year or so data only capture recent and not historical transhumant habits.

The first observation is that only 57% of households sampled in March practiced transhumance, compared to the 70% and 90% for the June and October surveys respectively. The reason more ‘sedentary’ households were sampled during the

March survey is that these households were selected by default as the survey coincided with peak dry season and lack of grazing in the KGR, and the transhumant households had taken their cattle out of the KGR. The figure of 90% for the October survey corresponds to the end of the wet season and with the large influx of new immigrants into the area. KGR was overgrazed, placing pressure on some households to move some or all of their cattle out of KGR. Most households reported taking their animals out of KGR at some point with only a minority staying in KGR all year long. From the perspective of disease transmission animals are exposed to both risk factors and factors mitigating risk both within KGR but also in the areas in which they practice transhumance.

From the survey in June 2011, most households practice dry season transhumance when grazing in the KGR is poor. More than 50% of transhumant households take their cattle out during the wet season, which indicates the carrying capacity of the KGR is insufficient to sustain the current cattle populations. This is more marked in the October survey, with over 80% of transhumant households taking their cattle out of the KGR either in the wet season or during both the wet and dry seasons. There is no pattern of higher or lower percentage of transhumant households across blocks.

Survey	**Number HH practicing transhumance (%)**						
	Block 1	**Block 2**	**Block 3**	**Block 4**	**Block 5**	**Block 6**	**Overall**
March	8/15 (53.3)	9/26 (36)	8/11 (72.7)	4/4 (100)	0/1	NA	26/56 (56.5)
June	4/6 (66.7)	8/13 (61.5)	3/6 (50.0)	8/9 (88.8)	4/4 (100)	0/1	27/39 (69.2)
Dry	*3/4 (75.0)*	*7/8 (87.5)*	*0*	*1/8 (12.5)*	*1/4 (25.0)*	*0*	*12/27 (44.4)*
Wet	*0*	*0*	*2/3 (66.7)*	*2/8 (25.0)*	*1/4 (25.0)*	*0*	*5/27 (18.5)*
Dry & Wet	*1/4 (25.0)*	*1/8 (12.5)*	*2/3 (33.3)*	*5/8 (62.5)*	*2/4 (50.0)*	*0*	*10/27 (37.0)*
October	6/6 (100)	15/16 (93.8)	5/7 (71.4)	5/6 (83.3)	1/1 (100)	1/1 (100)	33/37 (89.2)
Dry	*0*	*3/15 (20.0)*	*1/5 (20.0)*	*0*	*0*	*0*	*4/33 (12.1)*
Wet	*0*	*3/15 (20.0)*	*2/5 (40.0)*	*3/5 (60.0)*	*1/1 (100)*	*1/1 (100)*	*10 /33 (30.3)*
Dry & Wet	*6/6 (100)*	*9/15 (60.0)*	*2/5 (40.0)*	*2/5 (40.0)*	*0*	*0*	*19/33 (57.6)*

Table 32 Number and percentage of households sampled from each block during March, June and October practising dry +/- wet season transhumance

There is no significant difference between percentage of households migrating out of the KGR and year household settled in the grazing reserve, consistently 60-70% for

all households. There was no correlation between number of years of habitation in the KGR and percentage of herd taken on transhumance. As household wealth increases, so does the tendency to take cattle out of the KGR on transhumance since the need to practicing transhumance is influenced by the herd size. As herd size increases, so do the percentage of households of that herd size taking their cattle out on transhumance. Herds with less than 50 animals require less grazing, and can sustain the small cattle numbers on the grazing available within KGR. Large herds, however, need to leave KGR to find supplementary grazing.

The number of cattle herds taken on transhumance (during both the dry and wet season for the June and October surveys) is shown in Figure 60. Of all households sampled across all surveys, approximately 65% take all or some of the herd away for transhumance at some point during the year. Under half of the households stay in the KGR all year. Some households are counted twice, as they practice transhumance during both and wet and dry season, and their percentage herd transhumance is plotted separately for both seasons (Figure 60).

Of those households that practice transhumance, most take all animals away and a few take less than half their herd away. The number of households taking their cattle away on dry season transhumance is higher than that those taken on wet season transhumance. In the survey undertaken in October 2011, a large number of households also took their cattle out during the wet season (due to lack of grazing due to population pressure following mass-transhumance April-May 2011). A greater number of households take 100% of their herds out during the dry season. During the wet season, households only take a proportion of their herd out of KGR reflecting grazing pressures influenced not only by number of animals but also on availability of grazing. More grazing is available during the wet season and a lower proportion of cattle from a particular herd are forced to graze elsewhere.

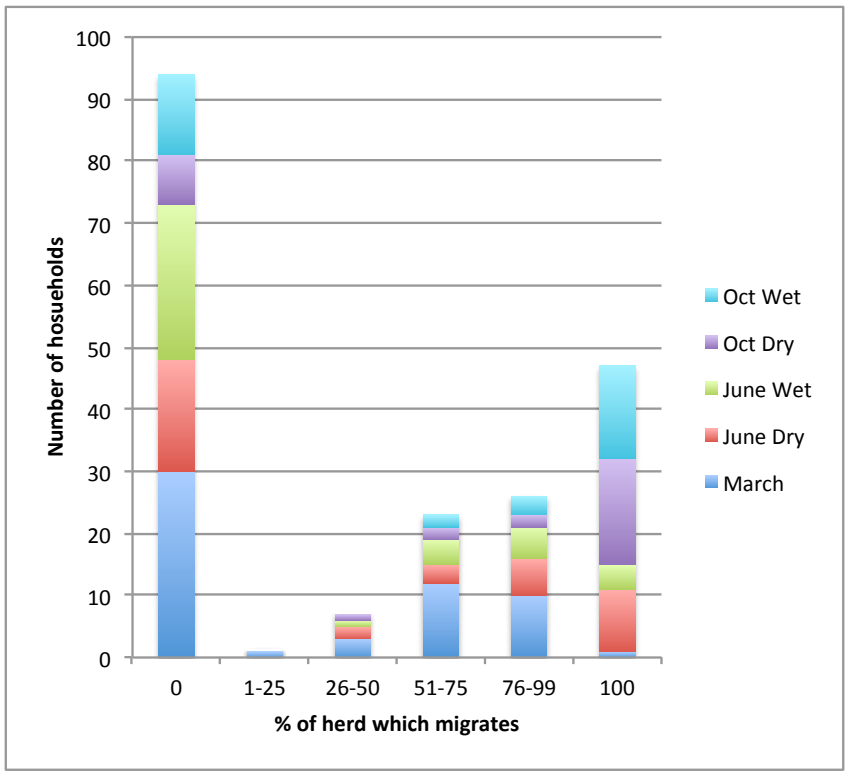


Figure 60 Number of households which take 0, 1-25, 26-50, 51-75 and 75-100% of their cattle on transhumance, categorised according to survey and season

Some households leave animals behind at the KGR homestead rather than take out all of their cattle (Figure 60). Keeping lactating females with young calves at foot within KGR not only provides milk for the family (only a few family members accompany the cattle on transhumance), and the stress induced by transhumance on very young calves, pregnant females in their last trimester and sick or old animals is to be avoided. In general the healthy animals are sent on transhumance, and some households choose to send all males or sexually mature females whose fertility will benefit from the improved grazing. Some households reported selecting animals 'randomly' where no specific selection criteria were applied. Others preferentially send sexually mature females on transhumance to promote optimal fertility through better nutrition, leaving males at home as they can tolerate the poor grazing in KGR.

5.1.3 When?

Seasonal variation in grazing resources influences the necessity for transhumance from KGR. The wet season normally begins in April, extending to October, although the duration and intensity of each season is liable to fluctuations (Awogbade, 1983).

Focus group discussions revealed that the onset of the wet season has become more delayed each year. On average, the wet and dry seasons last for 6 months each. During interviews in March 2011, respondents were asked about dry season transhumance. Focus group discussions revealed that households practicing transhumance during dry +/- wet seasons: *"Earlier settlers hardly go away on transhumance during the rainy season; people who take their animals away during the wet season are the new refugees"*.

Figure 61 shows that the highest frequency of households will leave for dry season transhumance in November or December and will return when a reliable source informs them that the rains have returned to the KGR. Most households going on wet season transhumance leave in June, coming back in November. The highest frequency of dry and wet season transhumance is 6 and 5 months respectively (Figure 62). Such lengthy transhumance, during the wet and dry seasons indicates that the grazing resources of the KGR are not sufficient to sustain the entire cattle population of all households living in KGR. Figure 63 shows that of households that practice transhumance, a surprisingly large number will only spend 1 month with their cattle in the KGR, although the majority will spend 7 months in KGR.

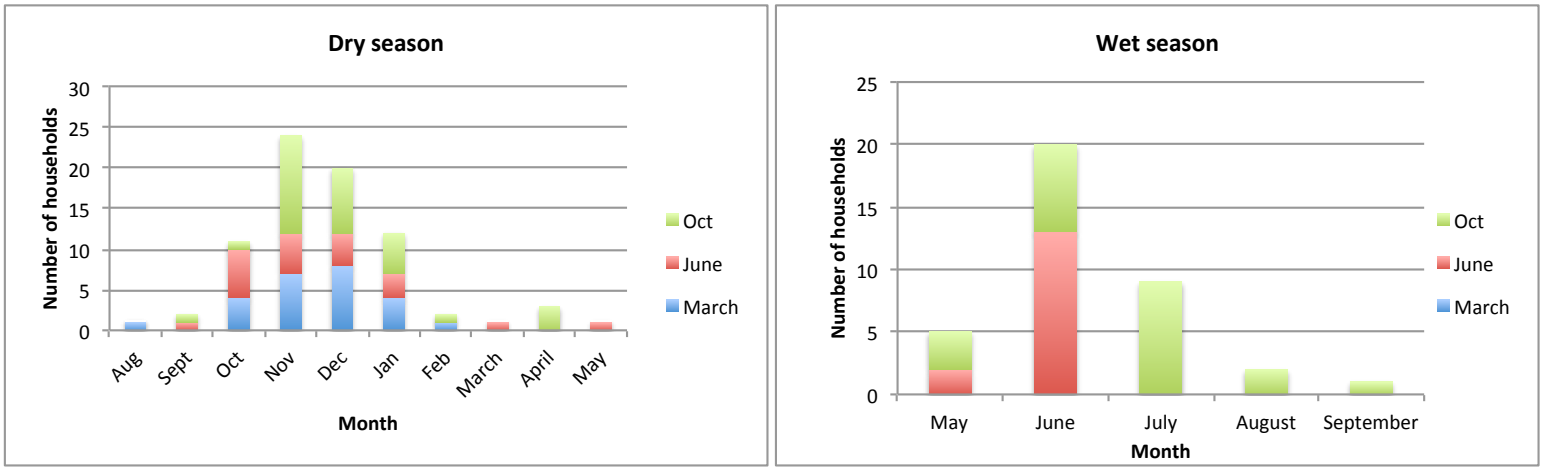


Figure 61 Month households leave KGR to go on dry season (left panel) and wet season (right panel) transhumance, subdivided for the March, June and October surveys

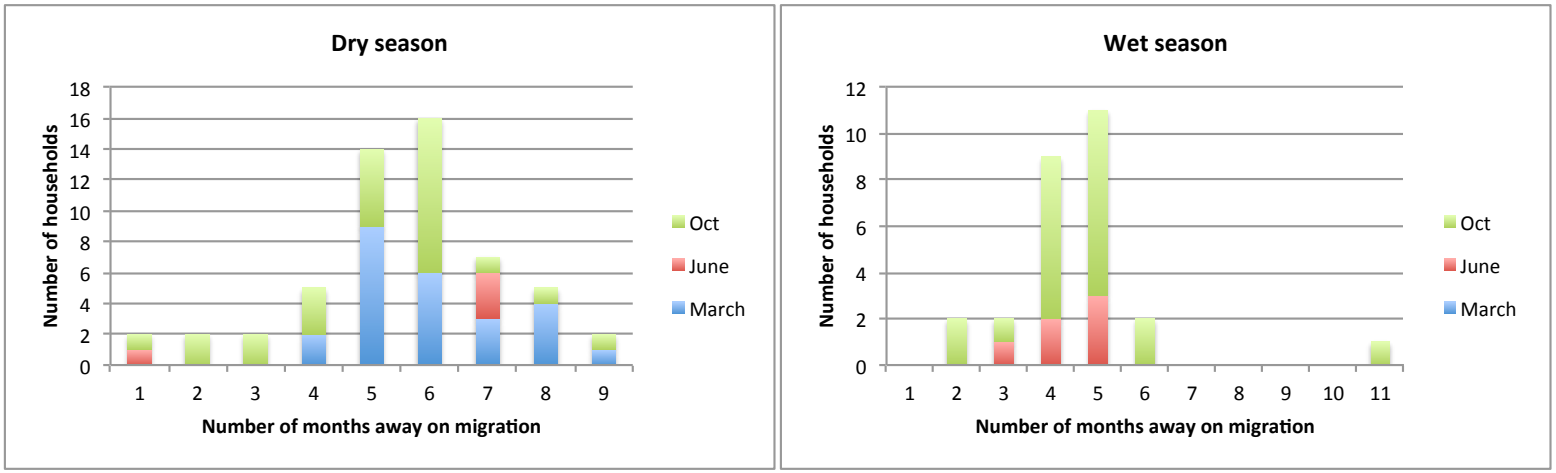


Figure 62 Duration of dry and wet season transhumance in months for March, June and October surveys

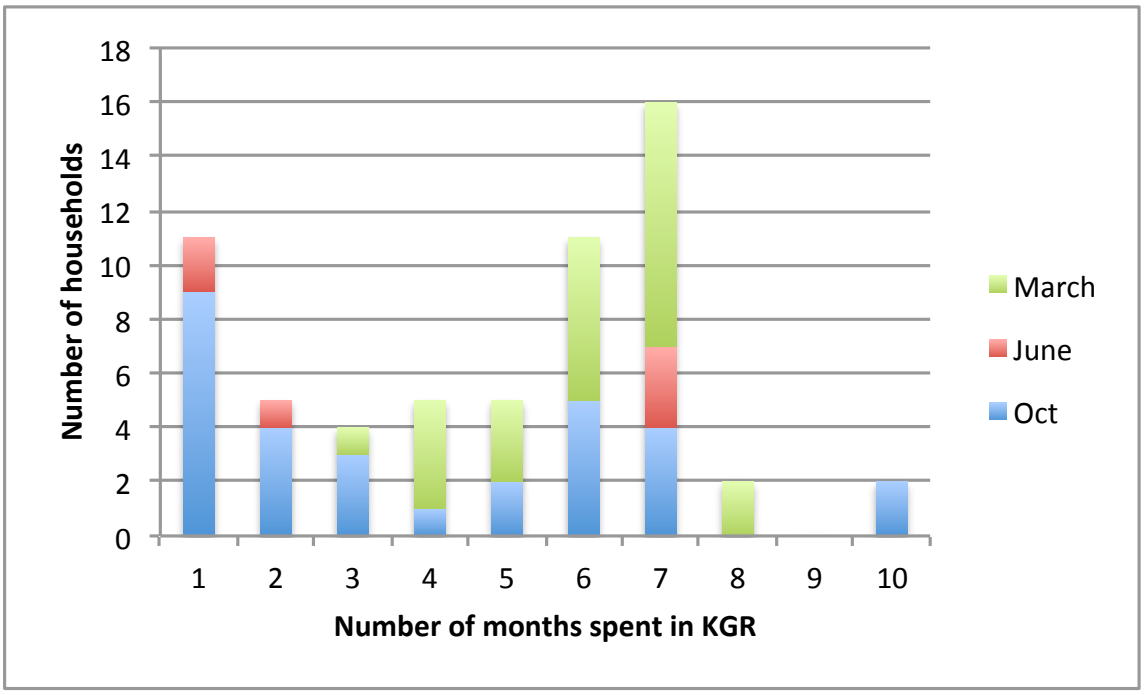


Figure 63 Number months spent in KGR by cattle

5.1.4 Where, why, who?

About 40% of households undertaking transhumance (dry and/or wet) travel between 40-80 km and 20% of households seek pasture closer to the KGR (within a 20-30 km radius). The remaining households travel 100 to 600 km to reach their destination of choice (Figure 64). When asked why the household head choses a particular location for transhumance, over half of responses referred to better grazing. The June and October 2011 surveys coincided with a period of brutal post-election violence, which explains why over 20 % of households stated absence of violence as a primary criterion for destination. Only two households mentioned absence of tsetse as a motivational factor. A few households mentioned that they had family members at the transhumance destination and that they were '*used to the place'* (Figure 65).

During the March survey households were also asked if they returned to the same place every year. While 56% stated that they returned to the same general area, 44% of transhumant households change the location of their dry and/or wet season transhumance based on the local socio-political and environmental conditions.

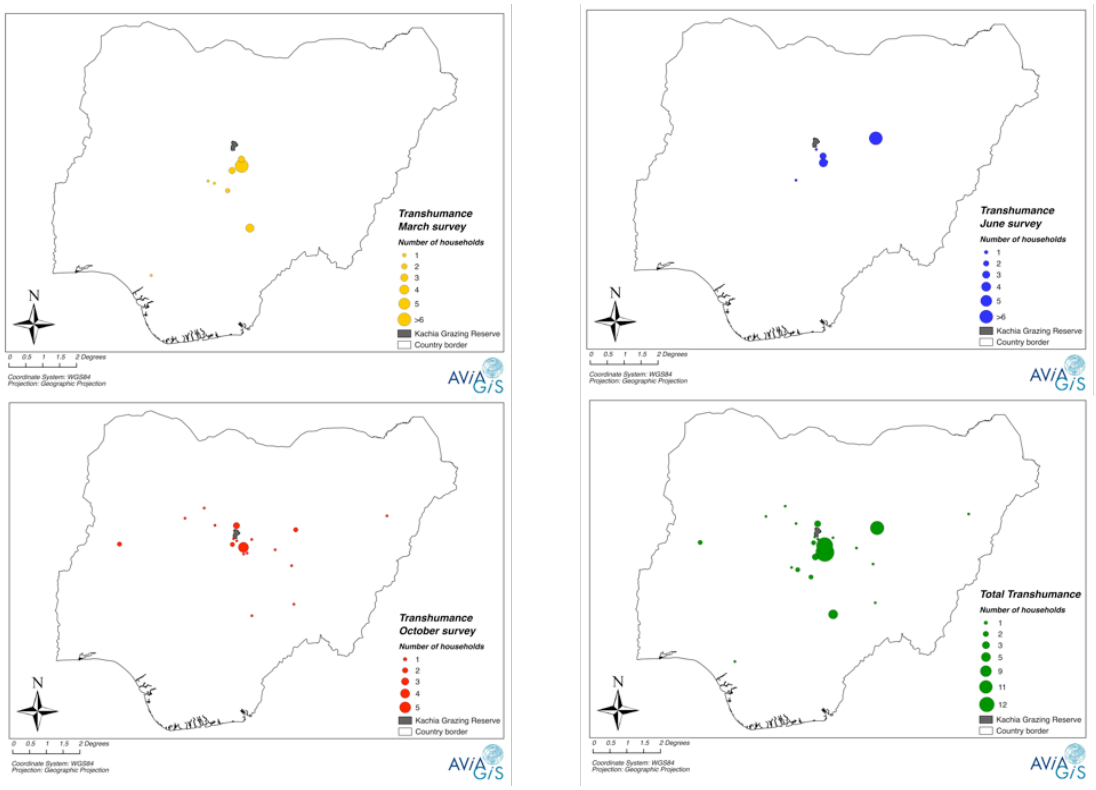


Figure 64 Transhumance destination based on March (top left), June (top right), October (bottom left) and all surveys (bottom right)

The majority of households described poor quality and scarcity of water and grazing as the primary motivator for migrating from KGR. They commented that the KGR was overgrazed. A minority described migrating due to tsetse fly challenge (Figure 65). "*Most of those that go far away are new settlers or newcomers that have come in the last two years, those of us that have settled here for a long time do not go far*".

Figure 64 shows that transhumance destination is more dispersed for the October survey (which contains a high number of newcomers). The reason given for wet season transhumance was: "*When the newcomers came they discovered that KGR has limited grasses, and they were more motivated to go on transhumance because they have come from areas which had a lot of grass*".

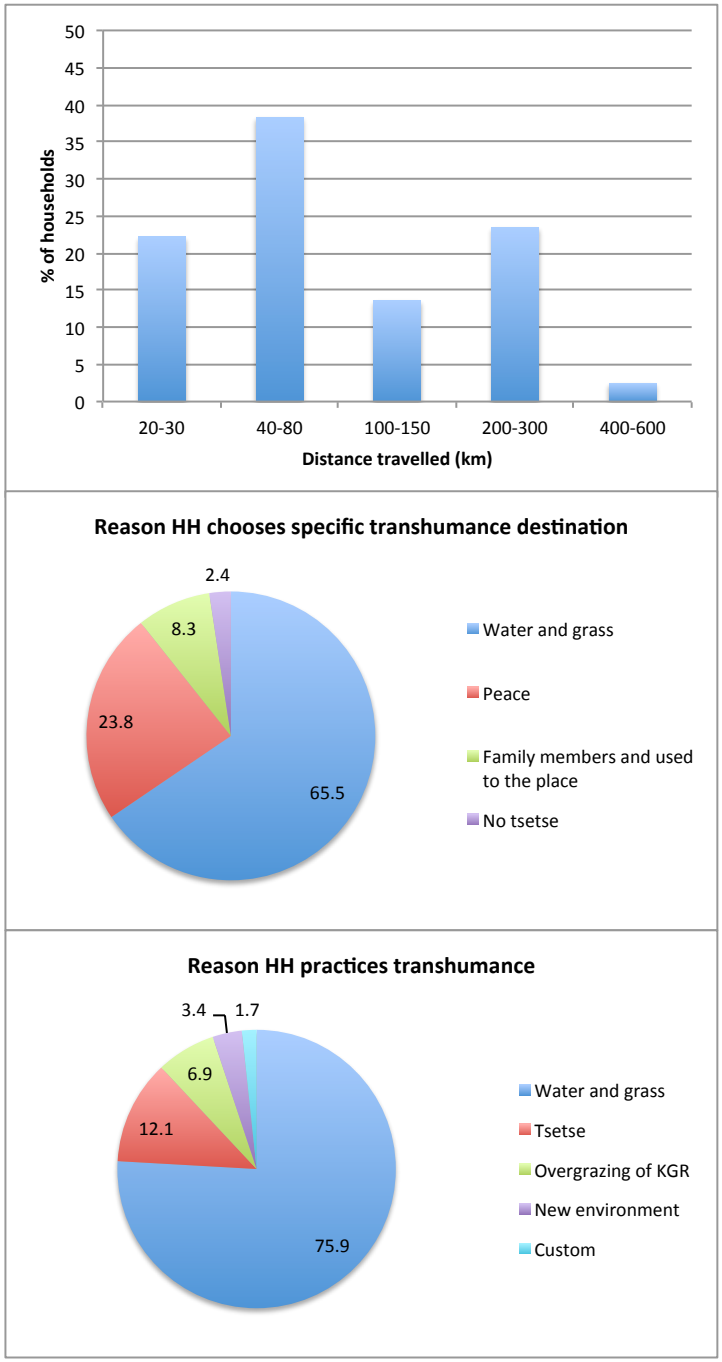


Figure 65 Percentage of responses for HH sampled in March, June and October on distance travelled to reach transhumance destination (top panel), reason for choosing destination (middle panel) and reason for going on transhumance (bottom panel)

One or two young men usually accompany cattle on their transhumance and assume responsibility for the herd. The household head decides which cattle are to go on transhumance and sends one or more of his sons to take the cattle to his location of choice. If the household head is young, he may request that some of his younger brothers perform this task. Some households will employ young boys, (not always

Fulani), for this task. In the survey of March 2011 respondents were asked who went on transhumance, and the majority stated this was the role of the oldest sons (married and unmarried) of the HHH (Figure 66). Transhumance is a huge responsibility and more experienced household members are preferentially selected.

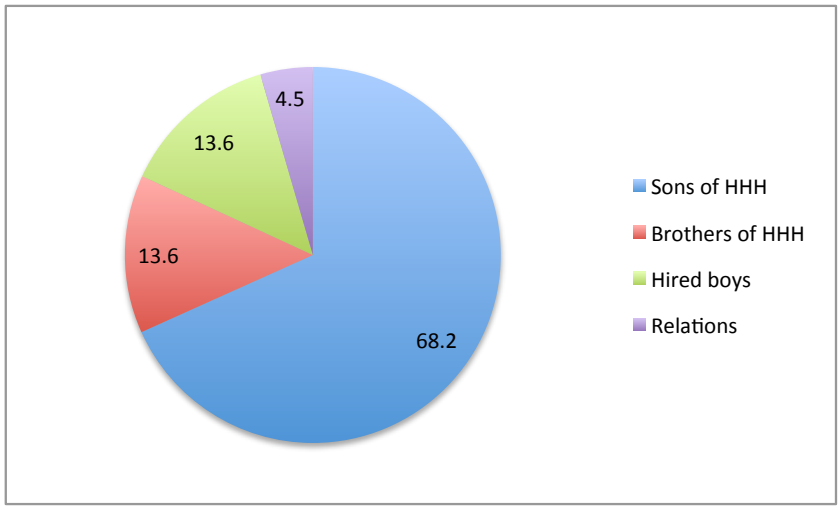


Figure 66 Percentage of household responses on person sent to accompany cattle on transhumance, March survey

5.2 Cattle Productivity

Consideration of livestock management choices is important as herd structure and dynamics are products not only of technical parameters of production but also of social dynamics and the relationship of herders to productive factors (Amanor, 1995). Herd size, herd composition and herd dynamics are discussed in this section with the social factors of relevance to productivity and livestock management.

5.2.1 Breeds of cattle

Cattle owned by the Fulani in Nigeria are zebu animals. Cattle maintained in KGR include predominantly the 'Bunaji' or 'White Fulani' (a white, black-eared and medium-horned breed) and to a lesser extent the 'Rahaji' or 'Red Bororo' cattle. Rahaji cattle are deep-burgundy coloured with pendulous ears and thick horns; adapted to arid and semi-arid regions. Fulani consider the Rahaji a prestigious breed (Blench, 1999) and many herds of 'white' cattle include a few Rahaji for crossbreeding. Some households in KGR keep Friesian bulls to improve the milk production but owners of these exotic breeds report high mortality: *"These animals need more food to sustain and they are more prone to death if sick"*.

5.2.2 Cattle keeping and the cattle complex

Cattle play a cultural role around which pastoral communities structure activities and traditions. The acquisition of stock and ensuring its wellbeing has been described as a means in itself rather than a means to an end (van Raay, 1975). This strong (and some would argue irrational) liking for cattle is called the 'cattle complex'; '*a strong attachment for cattle, manifested in love for and identification with the animals and in dislike of killing them except in a ritual context*' (Herskovits, 1952).

This close bond between a man and herd means that herdsmen sometimes know their cattle better than they know their own children. During a trip to the central market area while undertaking this research I came across a 40 year old man in tears being comforted by acquaintances. Knowing I was a vet, the group sought my advice and I was informed that the man was grieving the loss of one of his favourite cows. Fulani men give each of their cattle a name and have such a strong emotional attachment to their cows that the loss of child is often less distressing than losing a favourite animal. Fulani cattle are companion animals, rather than livestock.

This 'irrational' love for cattle has been proposed by some researchers and policy-makers to be the main factor motivating pastoralists to infinitely increase the size of their herd (regardless of the carrying capacity of the land). Numerous authors have expressed the view that traditional pastoralism constitutes 'overstocking' and 'inefficient management' of animals beyond their economic and reproductive function (Brokensha et al., 1977, Western and Finch, 1987). This argument is captured by van Raay (1975), who states that; '*cattle are wealth for social rather than economic purposes, pointing to the existence of an ideology in which emotions prevail over rational considerations*.'

These opinions come from comparison of traditional pastoral systems to modern systems of animal production, with regards to efficiency measures of maximum output of products for the market with the minimum labour inputs. As Dahl and Hjort (1976) point out, that high input low output pastoralism fulfils subsistence needs, providing a livelihood and income source to a large number of people, which a modern system would not. Others consider that pastoralism achieves equilibrium

between the pastoral unit and the herd for working capacity and food output (Stenning, 1959, Hopen, 1958).

Animals satisfy a large range of uses including prestige-making, bartering potential or currency, sources of food and labour and insurance against disasters (Iro, 2009). The herd maximisation goal is argued to ensure subsistence security (Konczacki, 1978, Iro, 2009, van Raay, 1975). The risk pastoralists face from environmental conditions and disease, which can remove their sole asset and source of subsistence, primarily governs the motivation for maximising herds. Spencer, (1965) observed; '*A man who loses one-third of his stock is much better-off if he begins with 60 cows rather than with 6*.'

The longer-term objective of the approach is captured by van Raay (1975): '*The Fulani have learned to manipulate their animals, environment and fellow pastoralists in such a way as to maximise their chances to fill their bellies on a lasting basis'*.

A pastoralist has to carefully balance the act of managing a unique and risky source of capital, to ensure the survival of present and future generations, (as cattle are inherited from father to son). Having herds is the difference between wealth and poverty, and also between life and death.

The universal and primary objective of pastoralists (Fulani included) is to maximise herd size and it is essential to understand the factors which govern herd size, herd composition and herd dynamics. In the following section cattle productivity is explored in the KGR community, which despite having diversified their sources of income and subsistence with crop farming and off-farm activities (business, casual labour and salaried-work) still adhere to the pastoralist tradition of maximising their number of cattle, and all the livestock management decisions which go with it.

5.2.3 Herd size

Herd sizes in the KGR, as based on data from the March, June and October surveys, was discussed in Chapter 4. In this chapter the difficulty of obtaining accurate data on herd size and cattle numbers in pastoralist systems is discussed. Accurate estimates of herd size are key for analysis of herd composition and herd dynamics since most parameters are calculated as a proportion of the total herd size. The two

most relevant factors: the complexities of defining what constitutes a herd, and the reluctance of pastoralists to discuss cattle numbers are explored.

5.2.3.1 The definition of a herd

Herds are difficult to enumerate as the criteria used to define a unit of cattle can be based on different factors, including management units, property rights and/or the domestic unit that depends on it for subsistence. A 'herd' managed as a single unit can be made up of multiple sub-herds, each of which is the property of a separate individual. A single herd could consist of multiple sub-herds of cattle owned by a single person but managed as separate units in different locations.

The tendency of pastoralist households to divide their cattle into one subsistence herd and one or several reserve herds, so not all of a household's cattle is kept together in one location all year long is described by Dahl and Hjort (1976). This means herd numbers fluctuate over time from division or re-grouping of herds and sub-herds. Seasonal differences in herd size can also occur due to a general practice of splitting the herd for grazing (Jabbar et al., 1995). There is the added complication of loaning of cattle to kinsmen and gifting of cattle from father to son or from husband to wife as a form of bride price. The herd managed by one household as a single unit may comprise cattle owned by the household head, his wives, his children and even cattle he has been given on loan from other households. When respondents are asked to enumerate their herd size, responses can be ambiguous.

5.2.3.2 Cultural offense of counting stock

On top of the challenges of defining the herd is the reticence of pastoralists to count their stock due to superstitious beliefs. Below is an extract from (van Raay, 1975): *"A water spirit appeared to a Fulani boy who wandered the bush and promised him great wealth and prestige if he obeyed his orders. The boy was told to wait by a river until cattle emerged from the water. The boy did so and when the first animals appeared he started to lead them away from the water into the bush. But hearing the swelling noise of the trampling animals behind him, he could not resist the temptation to ignore the advice of the spirit and look back in order to assess the size of his acquired wealth. The flow from the river ceased immediately. This taught the*

boy, and all pastoral Fulani since, a hard lesson. Counting animals amounts to fixing the size of the herd, inviting the sort of vicissitudes that set a ceiling to further increases."

The Fulani belief that counting stock challenges fate is shared with the Turkana pastoralists of East Africa (Dahl and Hjort, 1976). Reluctance to discuss cattle numbers can also be interpreted as 'good manners'. In a monetary society, at a gathering or individually, it would be considered rude to move from person to person asking them the value of their assets and their annual salary.

The historical reluctance of Fulani to supply accurate figures for the number of cattle in their herd is also illustrated in the unreliability of the figures given for cattle tax purposes (*jangali)* (Awogbade, 1983).

5.2.3.3 Assessing the quality of herd size data

Difficulties in obtaining and interpreting herd size data were experienced during the initial KGR survey in March 2011. These questionnaires did not capture the complexities of herd ownership. These were addressed in the June survey and included defining what a herd was and applying a method of triangulation for collection of herd size data as described by Sutter (1987) to obtain more accurate measures of herd size. Individual cattle data from the March survey were included to examine herd composition but data relating to herd dynamics have been rejected for inconsistencies between what different respondents had interpreted as 'the herd'. Hence herd dynamics have only been calculated based on the June survey data.

During the June 2011 survey, data on herd size was collected for the same households on multiple occasions (Table 33). The census, needed to fulfil the requirements of the State Government and a herd was defined as consisting of the number of cattle currently managed by the household and present in the KGR.

Capturing data on the entire capital value on which a single household based its economy was needed. In this questionnaire, administered alongside cattle sampling during a household visit, the herd was defined as above and household heads were asked about all animals owned by the household unit, including sub-herds or 'subsistence herds' kept on a holding outside of the KGR at the time of sampling, but

which are his property or the property of other persons in the household. In this way all cattle contributing to the household economy and not solely cattle currently present in the KGR were considered. While a specific animal was restrained for blood sampling, the household head (standing next to his herd) would be asked age, sex and reproductive status of each animal to derive accurate herd composition data.

The mean 62-65% difference between the census and blood sampling total estimate of herd size (Table 33, rows D and E) can be explained by the fact the census and animals blood sampled account for only a proportion of the herd present in KGR at the time of sampling, and do not include sub-herds owned by the household that are kept on another holding or are away on wet season transhumance. Comparison of the equivalent census data and total number of animals sampled for the same household revealed wildly and sometimes comically divergent figures, but were in the main fairly consistent (similarity 62.5 and 65.2%). The 7% difference was probably due to the fact that we did not blood sample calves less than 6 months old, as confirmed by a total calf population in the June survey of 12.9% of the herd (Table 38).

	Herd size assessment method	**Mean herd size**	**s.d herd size**	**Total cattle population**	**% of cattle population obtained in A**	**% lower than A (A–B, C or D or E)/A**
A	Questionnaire Qu.401&402	146.1	247.7	5698	100.0	0.0
B	Questionnaire Qu.301	131.0	244.9	5110	89.7	10.3
C	HH info form	90.4	90.2	3617	63.5	36.5
D	Census	53.4	75.5	2136	37.5	62.5
E	Blood sampling	49.5	29.3	1981	34.8	65.2

Table 33 Different herd sizes quoted by household head for households sampled during June survey and June census

The source of data in ‘C’ corresponds to data collected upon arrival at a household for sampling whereby the household head would be asked how many cattle his household owned for the purpose of preparing de-wormers (to be administered alongside during the sampling). De-wormers, as incentives, encouraged herdsmen to stay the time required for their whole herd to be sampled, rather than leave halfway because sampling was eating into grazing time. However, the use of de-wormers may also have caused farmers to over inflate their herd size estimates to obtain more de-

wormers than there were cattle, to acquire doses left over for future use (HH info data is approximately 30% higher than the sum of animals sampled).

The recording of total herd size on a separate form was designed to complement the individual cattle data and to account for any calves or other animals not blood sampled and that would be missed. This could in part contribute to the discrepancy.

When blood sampling was completed, the household head would be taken aside for the questionnaire. Questions about cattle ownership at household level were asked in two separate sections. In the first section, the HHH was asked the overall number of cattle and other livestock owned by his household (Figure 67). The estimate given was found to be 10% less than what is regarded as the most accurate estimate of the overall herd size, obtained in section 4 of the questionnaire (Figure 68). Pastoralists give lower-estimates of their global herd size than when the herd sizes are calculated from estimates of numbers of animals belonging to specific age and sex categories.

301. What livestock does your household own, own and keep in KGR and look after for other people?

Livestock type	**Number currently owned**[A] (A=B+C)	**Number owned and kept in KGR**[B]	**Number owned & kept on a holding out of reserve**[C]	**Number looked after for other people** (i.e. not owned by HH)
Cattle				
Sheep				
Goats				
Dogs				
Cats				
Chicken				
Turkey				
Guinea fowl				
Other (specify) _____				

Figure 67 Question 301 of June 2011 questionnaire

SECTION 4: CATTLE NUMBERS OVER THE PAST YEAR

*We would now like to ask some questions about what has happened to your cattle between June 2010 and June 2011, hence during **the last one year**.*

401. Please tell us some more about the **female cattle** your household owns in the KGR: how many female calves, heifers and cows do you own?

Type	Number of animals owned
Female calves less than 1 year old	
Heifers = Young females (females that have never calved but may be pregnant)	
Cows = Adult females (females that have calved at least once)	
TOTAL FEMALES	

402. Please tell us some more about the **male cattle** your household owns in the KGR: how many male calves, young males, castrated adult males and entire adult males do you own?

Type	Number of animals owned
Male calves less than 1 year old	
Young males (more than 1 year old but less than 4 years old)	
Castrated adult males (more than 4 years old)	
Entire adult males (more than 4 years old)	
TOTAL MALES	

Figure 68 Questions 401 and 402 of June 2011 questionnaire

5.2.4 Herd composition

5.2.4.1 Materials and methods

The investigation of herd composition is based on analysis of the individual animal data collected during sampling. Data examined include, age, sex and reproductive status (calving status for females and castration status for males) of all cattle in a sampled herd. Cattle are each given a name, and the household head and his sons can recount the age and reproductive history of each animal with high accuracy. To test the reliability of the ages given, these were compared with the age according to dentition, confirming the accuracy of estimates. Ageing cattle according the number of permanent teeth can only age cattle under the age of 5.

Both March and June 2011 survey data were analysed to investigate herd composition (no cattle were sampled during the October survey). For March, certain

households were excluded from the analysis (Table 34). Some animals belonging to selected households were away on dry season transhumance and individual data could not be collected. A separate herd composition analysis has been undertaken for households sampled for whom a percentage of the herd was away on transhumance (n=26) and those for whom all cattle was in KGR (n=23). This enabled differential analysis of composition of 'subsistence' sub-herds herds remaining at the homestead.

In March 2011, some herd owners left for grazing before the entire herd could be sampled and data collected on age and sex of animals. Herds for which data was collected for less than 80% of the herd (n=7) have been excluded from the analysis. (The use of de-wormers as incentives prevented this during the June survey). Six herds were excluded from the analysis because their transhumance status was not defined and data may not have represented all animals. For one household selected all animals were on transhumance and another herd was later found out not to be a resident of the KGR, these herds were excluded from the analysis.

Category	**Number HH**
Included in analysis	
Percentage of herd away on transhumance	26
All cattle in KGR and have data on 80-100% of herd	23
Excluded in analysis	
Don't know if have data for all herd as transhumance status undefined	6
All cattle in KGR, have data <80% of herd	7
100% of herd on transhumance, no data	1
Does not live in KGR	1
TOTAL	***64***

Table 34 Summary of data included and excluded in the herd composition analysis for the March survey

For the June survey, of all herds selected, none had animals away on transhumance as the sampling period coincided with the beginning of the wet season during which all animals return to the KGR. However, herd composition reflects the sub-herds managed by the household in the KGR, and not the aggregate of all herds managed by the household including cattle kept at another holding. Herd composition data reflects the sex and age of animals managed as a unit in the KGR, and not the different categories of all animals owned by individual households.

The analysis of herd composition has been divided into three parts; herd sex distribution, age distribution and finally 'lifestage' (combined data on sex, age and reproductive status to categorise individual cattle). More detailed lifestage analysis, comprising the categories described in Table 35, was undertaken initially. Each category of animal has a different function, role and economic value within the herd.

Calves, defined as cattle less than 1 year old, represent a key 'potential' asset. The calf value is minimal, but the prospective future value and function (dependent on survival) varies according to sex. Female calves, if fertile, will replace the female breeders in the herd. Female calves have a higher value than males due to the priority given to herd maximisation and milk production for subsistence and sale over the sale of stock. The greater the number of sexually mature females in a herd, the greater the opportunity for herd growth and the more milk for household consumption and sale will be produced. The 'future' value and function of male calves will depend on matrimonial genetic heritage (i.e. fertility, fecundity, disease history and milk capability of their dam), as Fulani believe that reproductive traits are inherited through the female line (Dahl and Hjort, 1976). If a male calf is selected to become a breeding bull, he will have higher intrinsic value than if destined for fattening since herd maximisation is prioritised over sale of animals.

The second group are juvenile males and females, in the 1-2 year age category. These animals will occasionally be sold (males more than females) in times of need, but due their sale is infrequent as they hold greater future potential value.

Sexual maturity in Fulani cattle occurs on average at 3-4 years old for males and females. Sexually mature animals have a higher value than sexually immature cattle as they can contribute to herd growth. For adult and sexually mature females, further subdivision according to their calving status applies. Animals that are calved are referred to as cows and are further subdivided according to age, corresponding to the different 'stages' of reproductive career. Cows of 3 to 4 years are at the beginning of their reproductive life. Those in the 5 to 7 year categories are in the intermediate phase, and those aged 8 to 10 are in the final stages. Cows older than 11 years have been included in a separate category and may be maintained by Fulani herdsmen due to their continued good, reproductive performance.

Male categories depend on whether they are retained for breeding or for selling purposes. Breeding males are kept entire, but 'fattening' males are not necessarily castrated. The decision to castrate, depends on their boisterousness once they reach sexual maturity, and is undertaken in bulls of 3 to 4 years old. Castrated males are referred to as 'steers' (or 'bullocks') and entire males are as bulls. Castration is widely practised to promote fattening, and to prevent bulls with poor genetic value breeding with females. The 'value' of a fattening male increases with age to 5 to 7 years depending on growth rate (males increase in size as they mature and fetch higher market prices). After 7 years the body condition of a steer body deteriorates, but Fulani may retain old animals of low market value in their herd due to the 'cattle complex', where herdsmen are unable to part with beloved animals. The notion that unproductive animals are hoarded for conservative or prestige reasons is considered false by some, who stress the importance of these animals as a reserve store of meat and cash (Dahl and Hjort, 1976). Even though pastoral nomadism is based on cows as producers of milk, bulls and bullocks have a value for human nutrition. Castrated males are also used for draft and some of the older animals classified as 'steers' have value as working animals. Here draft animals were categorised as a separate group, but sometimes a herd owner did not specify the use of animals for draft. In this study the 'entire male' category has been subdivided into the same age groups as for cows, as their reproductive/and or market value, peaks at 5-7 years old (both as breeding males and fattening males) and decreases beyond 5-7 years old.

Age (years)	**Male**		**Female**	
	Entire	**Castrated**	**Never calved**	**Calved**
>1	Calf male	NA	Calf female	NA
1-2	Juvenile male	NA	Juvenile female	NA
3-4	Bull 3-4	Steer 3-4 Draft	Heifer 3-4	Cow 3-4
5-7	Bull 5-7	Steer 5-7 Draft	Heifer 5 Heifer 6-7	Cow 5-7
8-10	Bull 8-10	Steer 8-10 Draft	NA	Cow 8-10
≥11	Bull Old	Steer Old Draft	NA	Cow Old

Table 35 Definition of 'lifestage' categories based on sex, age and reproductive status

The analysis of herd composition was also undertaken according to broader categories (Table 36) to be able to compare values for the KGR with those in the literature. The equivalent Table 35 categories are detailed for reference. Subdivision was firstly made according the sex, and then into calf categories, juvenile male/heifer and mature male and cow for sexually mature animals. The exact age of animals included in each group is shown in section 5.2.4.4. The 'juvenile' category is usually not found in intensive North American or European production systems, where animals are often mature from 18 months onwards, unlike extensive African systems where adulthood is usually age 4 years and over.

Sex	**Categories**	**Equivalent** Table 35 **categories**
Female	Calf female	Calf female
	Heifer	Juvenile female, Heifer 3-4, Heifer 5, Heifer 6-7
	Cow	Cow 3-4, Cow 5-7, Cow 8-10, Cow old
Male	Calf Male	Calf male
	Young Male	Juvenile male, Steer 3-4, Bull 3-4
	Mature Male	Steer 5-7, Steer 8-10, Steer old Bull 5-7, Bull 8-10, Bull old Draft

Table 36 General categories of reported in literature and corresponding 'lifestage' categories

For analysis of sex distribution, data corresponding the questions 401 and 402 of the questionnaire (Figure 68) were compared. This estimate corresponds to all cattle owned by the household unit, rather than just cattle present/ managed within KGR.

5.2.4.2 Sex ratio

The distribution of animals according to sex was examined for calves, sexually immature mature (animals under 4 years) and mature animals separately (Table 37). 'Form' data refers to the individual animal data collected during sampling, in contrast to questionnaire data collected based on household head recall.

The calf category comprises a higher percentage of females than males (51-66% of females). The ratio of male to female calves is between 1:1.04 and 1:1.92. The expectation would be a 1:1 ratio of male and female calves, but other researchers have similarly reported a higher proportion of female calves (Dahl and Hjort, 1976, Wagenaar et al., 1986). Female calves are favoured over males and allowed to suckle

from their dam for longer than their male counterparts (male suckling privileges are perceived inferior to the households need for milk. Female calves generally gain better nutrition with better chances of survival (Coulomb et al., 1980).

The pattern for dominance of females persists for the immature cattle category, except for the March survey, where numbers of male and female juveniles are almost equal. This may reflect events which occurred 1-4 years previously during the calfhood of this cohort of animals, whereby either female calf death rates were higher and equalled that of male death rates (consecutive bad years of grazing causing low milk yield), or male death rates were lower and equalled the lower female calf death rate (consecutive good years of grazing with good milk yields). van Raay (1975) who conducted similar censuses in northern Nigeria, reports that young bulls, 1-3 years old, occur in the same proportion as heifers in all surveys therefore his findings agree with those of the March survey.

A more likely explanation is that this equal ratio is artificial because the March data corresponds to households for which some animals had been sent away on transhumance, a higher proportion of immature males could have been left at the KGR homestead and more juvenile females sent on transhumance to reap the benefit of the better grazing conditions promoting fertility and conception rates.

The percentage of females in the sexually mature cattle category ranges between 82 and 91 indicating that most males are sold when they reach maturity around the age of 4. The ‘bull’ to ‘cow’ ratio is between 1: 4 and 1:11. This does not mean, however, that each bull is expected to serve only 4 to 11 females each. The actual number of females per breeding bull is higher because some of the males (roughly a third) included in the mature male category are castrated males (steers). Other authors have reported a ratio as low of 1:5 in cattle herds of the Pokot in Kenya, where more bulls than the necessary are kept as a security against losses (Schneider, 1957), but a mature bull can usually serve around 50 cows (Dahl and Hjort, 1976).

The purpose of steers is to act as a living store of meat for use in ritual ceremonies or in the dry season when milk production is low (Dahl and Hjort, 1976). Other reasons are to help manage the herd as male castrates keep the cows calm (Shaw, A., pers. comm.). Other authors have reported proportions of males to females within the adult

herd to be 1:5 in Maasai herds (Widstrand, 1972) and 1:7.47 in Western Sudan (Hunting, 1974), which is in agreement with the figures reported here.

Overall, the majority of herds in the KGR are comprised of 70-80% female and 20-30% male cattle (Figure 69). This is typical of pastoralists who bias their herds towards reproductive animals for herd growth and milk producers for subsistence and income of the household. This is identical to both of the van Raay (1975) surveys where female animals make up about 70% of the total herd. A percentage of 75% was reported for female cattle for Samburu herds in Kenya and for African nomads (Spencer, 1973, Demiruren, 1974), as well as for Datoga cattle in Tanzania (Sieff, 1999) who also describes herds composed of 70% female. It is only in areas where animal traction using male cattle is important that herds with more male than female cattle are found, notably in parts of Ethiopia where up to 70% of the herd may comprise males (Jemal and Hugh-Jones, 1995). In these cases the herd dynamics are such that the high proportion of males can only be sustained by buying in young male animals from other areas (Jemal and Hugh-Jones, 1995, Shaw et al., 2014).

A correlation was reported between herd size and sex distribution, whereby the percentage of females decreases and the percentage of males increases as the herd size increases (Dahl and Hjort, 1976). This was not observed in KGR. The few herds where the percentage of male to female cattle are roughly equivalent, correspond to transhumant herds sampled in March 2011 where more males stayed at the homestead (herdsmen preferentially sending the females for transhumance to promote better nutrition and fertility). This corroborates the findings based on the analysis of the questionnaire on transhumance behaviour for households that declared preferentially sending sexually mature females on transhumance.

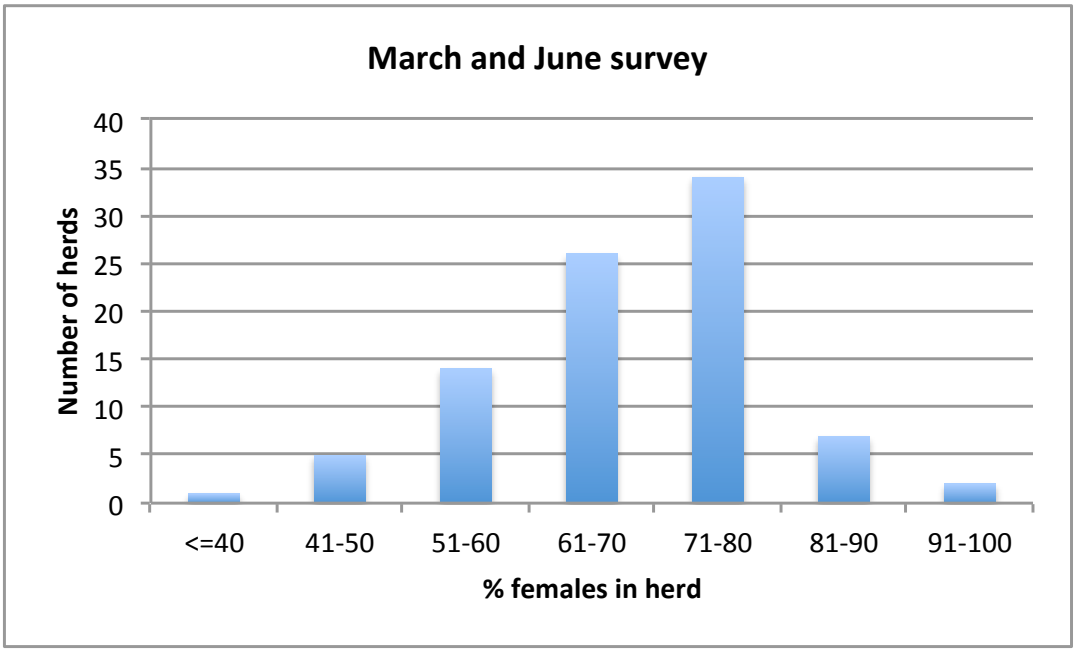


Figure 69 Frequency distribution of percentage of females in herd for March and June surveys

Age category (yrs)	Sex	March form	June form	June qu'aire
Calves (<1)	***No. F***	*118*	*130*	*1132*
	No. M	*79*	*125*	*591*
	Total no.	*197*	*255*	*1723*
	% F	59.9	51.0	65.7
	% M	40.1	49.0	34.3
	M:F ratio	1:1.49	1:1.04	1:1.92
Immature (1-4)	***No. F***	*306*	*574*	*1126*
	No. M	*309*	*328*	*656*
	Total no.	*615*	*902*	*1782*
	% F	49.8	63.6	63.2
	% M	50.2	36.4	36.8
	M:F ratio	1:0.99	1:1.75	1:1.72
Sexually mature (>4)	***No. F***	*504*	*702*	*1551*
	No. M	*48*	*77*	*353*
	Total no.	*552*	*779*	*1904*
	% F	91.3	90.1	81.5
	% M	8.7	9.9	18.5
	M:F ratio	1:10.50	1:9.12	1:4.39
Overall	***No. F***	*928*	*1406*	*3809*
	No. M	*452*	*575*	*1891*
	Total no.	*1380*	*1981*	*5700*
	% F	67.2	71.0	66.8
	% M	32.8	29.0	33.2
	M:F ratio	1:2.05	1:2.45	1:2.01

Table 37 Females (F) and Males (M) in each age category for March and June individual cattle data and June questionnaire data

5.2.4.3 Age distribution

The frequency distribution according to age for the transhumant and non-transhumant households of March and June surveys is shown in Figure 70. This shows a reduction in frequency with increasing age. The oldest cows were 23, 13 and 16 years old (March 2011 non-transhumant, March 2011 transhumant and June 2011 surveys respectively). The frequency of animals in age categories above 8 years drops to below 15 showing few cows are kept beyond their 8th year. The maximum age reported for males is of 8-9 years old (although one 13 year old male was recorded in March 2011). Most bulls exit the herd before they are 4 years old.

Comparison between transhumant and non-transhumant herds for the June survey shows a similar age distribution for both males and females. More, older females, over 7 years old remained in KGR include. These older females have less capacity to withstand the stress of the long trek. There is no difference between the number of young males in transhumant and non-transhumant households. The data support the premise that animals are chosen 'randomly' for transhumance. The data show that cattle are usually managed as cohorts. Households with more than 60 cattle will manage their cattle as two sub-herds. Non-transhumant households correspond to households with smaller herds (they do not need to the herd into multiple sub-herds which need to be managed in different locations due to limited access to grazing).

For female calves in all surveys and for male calves in the June 2011 survey, there is a drop in frequency going from the <1 to the one-year category, which can be explained by high calf mortality. For males in the March survey, both for transhumant and non-transhumant households, the frequency of one-year old calves is higher than for calves less than a year old. Male calves born in the year before the March survey may have perished due to poor grazing conditions and lack of milk from their dams. The sum of female calves for transhumant households exceded 100 individuals but the sum of male calves is almost half that of the the females. This trend is not observed in the June survey because the high male calf mortality could have been limited to herds that stayed in the KGR during the dry season, whereas the June survey incorporates households which had taken all of their animals out of the KGR during the dry season and also new immigrants which had not been inhabited or been exposed to KGR during the previous dry season.

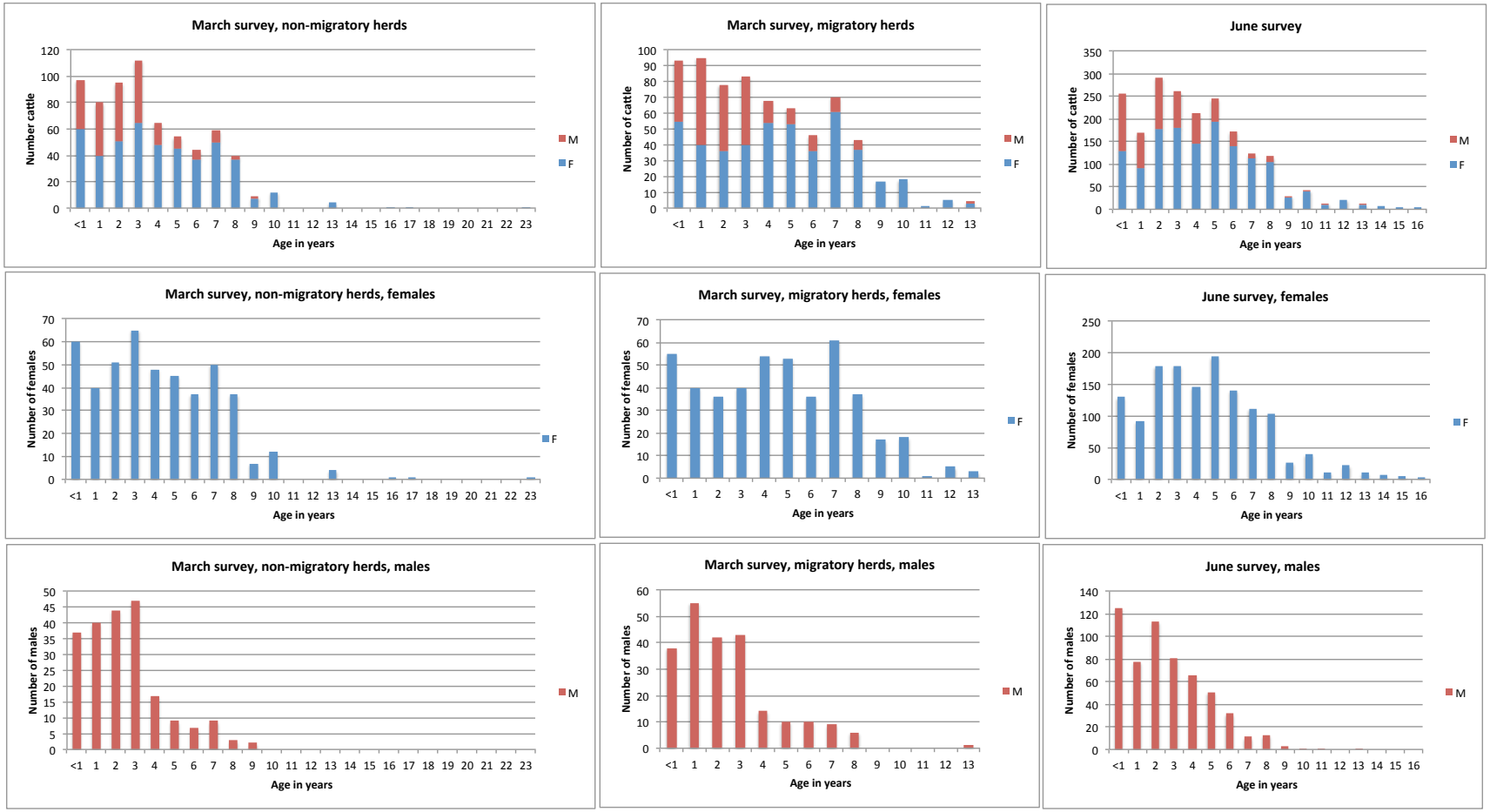


Figure 70 Age distribution for males (M) and females (F) of herds sampled where 100% of animals were in KGR (non-transhumant) and herds where proportion of herd was away on dry season transhumance (transhumant) herds for March survey and all herds for June survey

5.2.4.4 Distribution according to 'lifestage'

The number and percentage of animals in each 'lifestage' category across the surveys are shown in Table 38.

Lifestage	March survey						June survey		March&June	
	Non-mig herds		Mig herds		Overall					
	N	%	N	%	N	%	N	%	N	%
Calf female	63	9.2	55	7.9	118	8.6	130	6.6	248	7.4
Calf male	41	6.0	38	5.5	7	5.7	125	6.3	204	6.1
Juvenile female	93	13.5	76	11.0	169	12.2	271	13.7	440	13.1
Juvenile male	88	12.8	99	14.3	187	13.6	191	9.6	378	11.2
Steer 3-4	32	4.7	23	3.3	55	4.0	6	0.3	61	1.8
Steer 5-7	3	0.4	7	1.0	10	0.7	23	1.2	33	1.0
Steer 8-10	0	0.0	5	0.7	5	0.4	6	0.3	11	0.3
Steer old 10+	0	0.0	0	0.0	0	0.0	2	0.1	2	0.1
Bull 3-4	32	4.7	35	5.1	67	4.9	131	6.6	198	5.9
Bull 5-7	20	2.9	21	3.0	41	3.0	67	3.4	108	3.2
Bull 8-10	5	0.7	2	0.3	7	0.5	10	0.5	17	0.5
Heifer 3-4	73	10.6	54	7.8	127	9.2	277	14.0	404	12.0
Heifer 5	5	0.7	5	0.7	10	0.7	20	1.0	30	0.9
Heifer 6-7	0	0.0	0	0.0	0	0.0	6	0.3	6	0.2
Cow 3-4	40	5.8	40	5.8	80	5.8	49	2.5	129	3.8
Cow 5-7	129	18.8	152	21.9	281	20.4	423	21.4	704	20.9
Cow 8-10	56	8.2	71	10.2	127	9.2	171	8.6	298	8.9
Cow old 10+	7	1.0	9	1.3	16	1.2	59	3.0	75	2.2
Draft male 4+	0	0.0	1	0.1	1	0.1	14	0.7	15	0.4
Sub-total females	466	67.8	462	66.6	928	67.3	1406	71.1	2334	69.4
Sub-total males	221	32.2	231	33.3	380	32.9	575	29.0	1027	30.5
Grand Total	**687**	**100.0**	**693**	**100.0**	**1380**	**100.0**	**1981**	**100.0**	**3361**	**100.0**

Table 38 Number and percentage of cattle in each lifestage category for transhumant and non-transhumant herds of March survey, June survey, and both surveys combined

The number of male calves in transhumant and non-transhumant herds for the March survey is lower than the number of female calves. Numbers of male and female juveniles are roughly equivalent, a trend observed for the March but not the June survey. New immigrant households were forced to sell some of their juvenile males to pay for costs associated with relocating to the KGR. The majority of steers are in the 3-4 year old category for the March survey, which reinforces the fact that most castrated males are sold after the 4th year of life. The June survey reveals a different

trend, with a higher frequency of steers in the 5-7 year old category. This could be interpreted as June households (which incorporate a large number of new immigrant households and households which take all cattle out of KGR during the dry season) having the luxury of holding on to their males longer. As has been described by Sieff (1999) and Sutter (1987) sale of younger animals is undertaken by 'poorer' households who have to part with stock earlier than wealthier households. Poverty analysis revealed that March households were not poorer than those sampled during June 2011. An explanation for this trend is the need for new immigrant households to part with 3-4 year old steers to meet the cash demands associated with the move to the KGR. Sale or slaughter is not practised when animals are most valuable or fattest, but rather when the human need is most pressing (Dahl and Hjort, 1976).

For bulls, the number of animals in each age category goes down from 5-6% for the 3 to 4 age category to 3% for bulls aged 5-7 years old and 0.5% for old bulls. This suggests that breeding bulls and entire fattening bulls are sold from 4 years onwards.

Heifers (sexually mature females not yet calved) are predominantly in the 3-4 years of age category. Some females (n= 36 or 1% of all animals) have not had a calf at 5 years or over and are sub or infertile. Fulani usually sell such cows at the age of 5 and only 6 beasts are still observed at 6 or 7 years old.

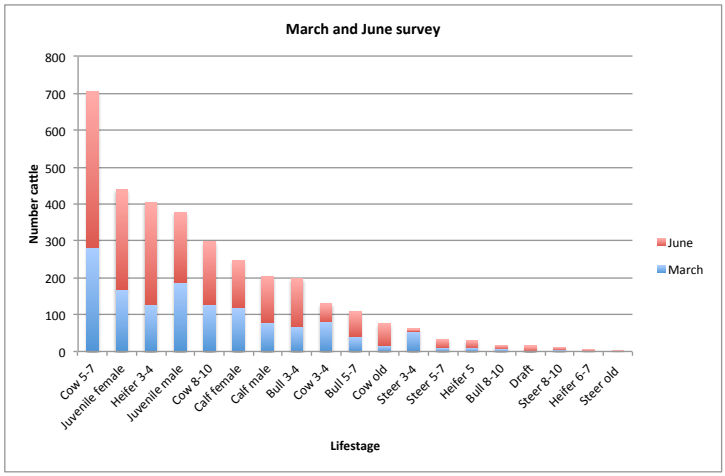


Figure 71 Number of cattle in each lifestage category for March and June surveys combined

Cows between 5 to 7 years old represent the category with the most animals (accounting for 20% of all cattle) (Figure 71), which emphasises the primary objective of herds to produce calves for herd maximisation and to provide milk for household subsistence. A small proportion of cows (between 7% and 16%) are aged

3 and 4, so calve before age 4. The number of cows in the older age categories gradually tapers off due to deaths and sales due to age-related loss in fertility.

Interpretation of data according to broader categories is shown in Table 39. Individual animal data from the June survey for to herd composition for animals kept only in KGR can be compared with data from the June questionnaire corresponding to all animals owned by households, including those kept outside of KGR.

Cows are the dominant category, accounting for 27-37% of the herd, followed by heifers, which account for 20 to 30% of the herd. In these systems a lot of followers (heifers) are reared. Some 70% of the herd is female, but only half of these are cows.

The aggregate herds have a greater percentage of female calves, almost 20% of the overall herd. The number of heifers and cows is lower and the percentage of calf males is higher. The average calf crop appears better for holdings outside of KGR.

Categories	**March- Form**		**June-Form**		**June-Qu'aire**	
	N	%	N	%	N	%
Calf Female	118	8.6	130	6.6	1132	19.9
Heifer	306	22.2	574	29.0	1126	19.8
Cow	504	36.5	702	35.4	1551	27.2
Calf Male	79	5.7	125	6.3	591	10.4
Young Male	309	22.4	328	16.6	656	11.5
Mature Male	64	4.6	122	6.2	644	11.3
Castrated	16	1.2	45	2.3	291	5.1
Entire	48	3.5	77	3.9	353	6.2
Total	1380	100.0	1981	100.0	5700	100

Table 39 Number and percentage of cattle in each category for the form data set of the March survey and the form and questionnaire data set of the June survey

Values obtained in this study are compared with figures for the Nigeria (Table 40) and for female cattle for pastoralist herds throughout Africa (Table 41).

Category	Age (yrs)	Percentage cattle				
		(Fricke, 1979)	(Pullan, 1979)	(Blench, 1984)	(van Raay, 1975)	(Otchere, 1982)
		Northern Kano	Jos Plateau sedentary	Mambila Plateau	Zaria	Kaduna plains
Calf female	< 1	6	9.5	14.2	10.1	11.4
Heifer	1 to 3-4	30.6	9	10.8	17.5	21.1
Cow	>3-4	38.8	45	32.9	40.5	32.4
Calf male	< 1	3.7	9.5	13.8	10.1	11.4
Immature male	1 to 3-4	14.2	7	9.4	13.4	2.8
Bull	>3-4	6.7	20	19.5	8.4	20.9
TOTAL	All	100	100	100.6	100	100

Table 40 Percentage of cattle in different age and sex categories quoted in other studies conducted in different regions of Nigeria
Source: adapted from (Amanor, 1995)

Estimated percentages of female calves in the average herd in KGR are similar to other estimates (Amanor, 1995), except for the June questionnaire estimate which at 20% exceeds the highest estimate of 14.2 quoted by Blench (1984). Percentage of heifers is variable, 31% (Fricke, 1979) to 9% (Pullan, 1979), and the estimate for KGR is closest to that of another study (Otchere, 1982). The estimate of the percentage of adult cows in the average herd in KGR is also similar to previously reported values for Nigeria. Table 41 shows the average KGR herd comprises 50% females. Some censuses regard females of over 2 years as cows (as would be the case in Europe) whereas in Africa it would be 4 years or more.

Pastoral group, Country	Category	Percentage	Reference
Kenya	Cows	50	(Widstrand, 1972)
West Sudan	Cows & heifers	68	(Hunting, 1974)
Karimojong, Uganda	Cows & heifers	49-85	(Dyson-Hudson and Dyson-Hudson, 1975)
Maasai, Kenya	Cows & heifers	44-51	(Widstrand, 1972)
Maasia, Kenya	Cows & heifers	60	(Roderick et al., 1998)
Maasai, Tanzania	Cows & heifers	53-61	(Jacobs, 1963)
West African Sahel	Females =>1	44	(Bremaud and Pagot, 1962)
Samburu, Kenya	Cows	57	(McKay, 1957)
Ethiopia	Adult cows	50	(Brown, 1973)
Peul, Niger Delta, Mali	Cows	38	(Wagenaar et al., 1986)
	Heifers	23	
	Cows & heifers	61	
Datoga, Tanzania	Cows 2 yrs to weaning first calf	55	(Sieff, 1999)

Table 41 Percentage contribution of sexually mature cattle to overall herd size in different contexts
Source: adapted from (Dahl and Hjort, 1976), other sources as listed

The lower percentage of male than female calves can be observed for other studies in Nigeria (Fricke, 1979, Blench, 1984). The main difference in the herd composition of KGR with that of other studies undertaken in Nigeria is the higher percentage of immature but lower mature males in Ladduga, which suggests that there may be a bigger need for KGR households to sell male cattle before they reach maturity due to cash needs. Amanor (1995) also describes that herds in sub-humid areas have a tendency to retain larger numbers of male immatures than in the arid-zone. Herders who seek to maximise the efficiency of their herd focus on the rapid production of calves, and sell the males before they reach their full potential growth.

5.2.5 Herd dynamics

Herd dynamics are affected by entries into (births and purchases), and exits out (death, sale, slaughter and giving away of animals as gifts) of the herd. These demographic processes are influenced by factors such as reproduction, mortality and household needs for off-take. Calving rates and commercial off-take are decided and influenced by herd management strategies while mortality is determined by external factors and requires adjustments in herd management to be made accordingly. To examine fertility and fecundity individual animal data from March and June 2011 were analysed. Investigation of fertility is based on the collection of data of number of calves each sampled cow has given birth to, and relation of this data to the age of the cow. Herd level questionnaire data from June 2011 was been used to investigate herd dynamics in terms of herd entries and exits (section 5.2.5.2).

5.2.5.1 Fertility and Fecundity

Fertility and fecundity drive the growth rate of herds. Nutrition and genetics have the highest impact on an animal's fertile period. Nutrition is related to availability of grazing, which is limited both during the dry season and wet season (due to high cattle densities) in the KGR, and is the main factor driving wet and dry season transhumance. The *Rahaji* and *Bunaji* are *Bos indicus* cattle and reach puberty later than *Bos taurus* (Mukasa-Mugerwa, 1989). The age of first birth for female cattle in KGR can be estimated by examining data on the age of individual heifers and cows which have given birth to 0 and 1 calf respectively (Table 42, Figure 72). Cattle with no calves have a median age of 3 years and cows with 1 calf a median age of 5 years. The age of first calving is therefore between 3 and 5 years.

Survey		**Number of calves given birth to**							
		0	**1**	**2**	**3**	**4**	**5**	**6 to 10**	**Total**
March	N cows	142	119	119	107	66	25	14	592
	% of total cows	24.0	20.1	20.1	18.1	11.1	4.2	2.4	100.0
	Mean	3.5	5.1	5.7	6.8	7.8	9.4	12.3	
	s.d.	0.7	1.4	1.2	1.3	1.4	1.7	4.9	
	Median	3	5	6	7	8	9	10	
June	N cows	302	180	181	136	78	73	46	996
	% of total cows	30.3	18.1	18.2	13.7	7.8	7.3	4.6	100.0
	Mean	3.5	5.1	6.0	7.2	8.2	9.7	11.8	
	s.d.	0.7	0.8	1.1	1.2	1.8	2.1	2.5	
	Median	3	5	6	7	8	9	12	

Table 42 Number, percentage, mean, s.d. and median cows that have given birth to 0, 1+ calves

For Fulani cattle in Zaria, Nigeria, age at first breeding was previously reported as 4.05 years and age at first calving of 4.75 (Akpa et al., 2012), similar to that reported here. In the 1950s an average age of 3.3 was reported for White Fulani cattle in northern Nigeria (Joshi et al., 1957). There are reports that heifers reach puberty earlier in transhumant than sedentary herds (Hunting, 1974).

The calving interval is thought to be the best index of a cattle herd's reproductive efficiency (Mukasa-Mugerwa, 1989). This is subdivided into 3 periods: gestation, which lasts 9-9.5 months for tropical cows, post-partum anoestrus (calving to first oestrus) and the service period (first post-partum oestrus to conception).

An estimate of calving interval (CI) was calculated for the March and June data combined using the following:

n= number of calves (for cattle ≥2 calves, individual June and March 2011 data)

a= age of cow in months (from individual June and March data)

p=age at puberty (30 months old)

g=gestation length (9 months)

CI = (a-p-g)/n

CI = (a – 39)/n

e.g. for a 7-year-old cow that has had 2 calves: CI= [(7*12)-39]/2 = 22.5 months

The average calving interval is similar for the March and June data (Table 43).

Data giving calving intervals of less than 12 months were excluded from the analysis (these data were exceptional and reflect either respondent bias or data entry errors).

The mean calving interval for KGR herds is 17 -18 months in agreement with Oyedipe et al. (1982) who report a calving interval of 14.2-18 months for white Fulani cattle. The highest frequency of cattle have a calving interval of 16 to 20 months, but surprisingly a substantial number animals have a low calving interval between 10-15 months. Calving intervals of 22.1 months have been reported for agropastoral herds in central Mali (Wilson, 1981). This correlates with what others have observed (for example in Gambia) where a subset of cows calve frequently and another group calves every two years (Shaw, A., pers. comm.).

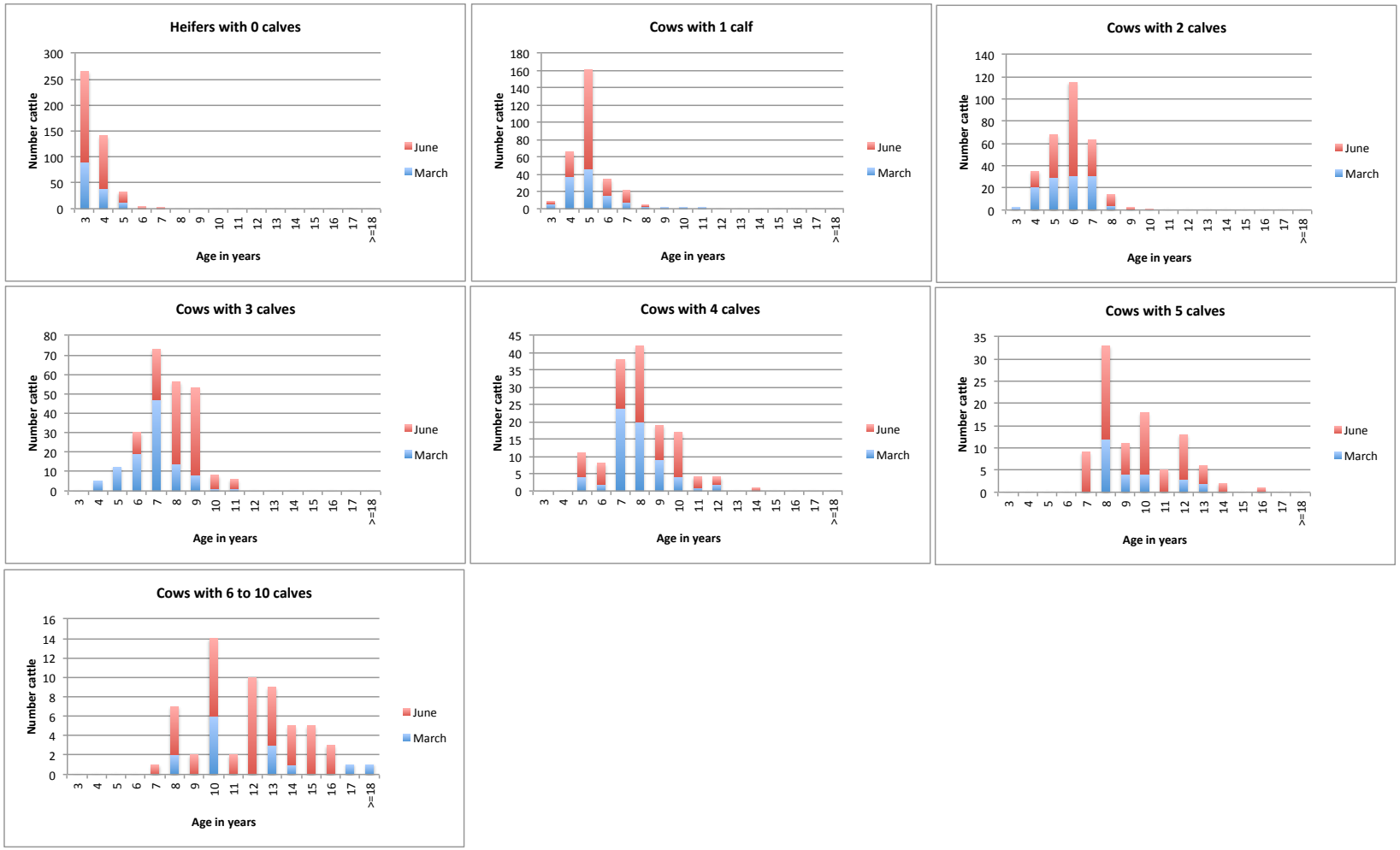


Figure 72 Frequency distribution of age of cows which have had 0, 1, 2, 3, 4, 5, and 6-10 calves, based on data from March and June surveys

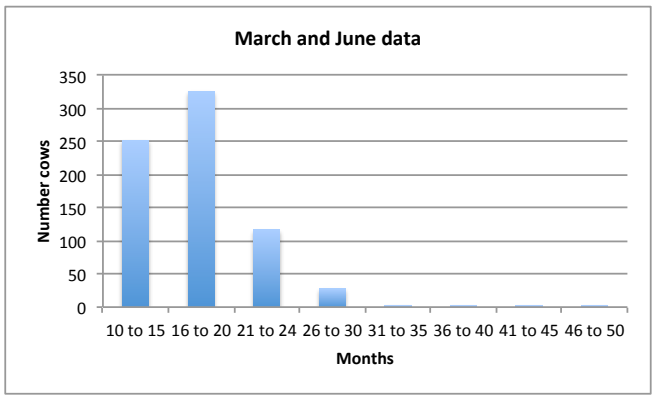


Figure 73 Frequency distribution calving intervals in months, based on data from March and June surveys

Calving interval (mths)	March	June
Mean	17.1	17.6
Standard deviation	4.9	4.9
Minimum	10	9.6
Lower quartile	12	14
Median	16	18
Upper quartile	20	20
Maximum	42	48

Table 43 Mean, s.d., and five point summary of calving interval for March and June surveys

The average number of calves born per cow depends not only on the fertility, but also on life expectancy. Fulani will keep cows until they are at least 8 years old or longer if they are reproductively proficient. To calculate the calf crop of a cow of normal life expectancy we have calculated the average number of calves born to three categories of cows: 1) cows of 6 years or older, 2) cows of 7 years or older, and 3) cows of 8 years or older. The data is summarised in Table 44 and shows that a cow will have on average, 3 to 4 calves during its reproductive lifetime. Demiruren (1974) gives the number of calves born per cow as lower or equal to 3, which is in agreement with our figure.

Other authors have reported estimates between 4 and 7 calves (Grunnet, 1962). White Fulani are reported to have an effective breeding life of around 10 years, which combined with their regular breeding, should yield a total of ten calves per lifetime (Dahl and Hjort, 1976). The data show that some cows did give a calf crop of 10, but this is very much a maximum and an exception. At the other extreme, some cows 6 years and over had only given one calf.

Survey	Number of calves	Age of cows		
		≥6 years	≥7 years	≥8 years
March	mean	3.2	3.5	4.2
	s.d.	1.6	1.6	1.8
	min	1	1	1
	Q1	2	3	3
	med	3	3	4
	Q3	4	4	5
	max	10	10	10
June	mean	3.4	3.9	4.5
	s.d.	1.7	1.6	1.6
	min	0	0	1
	Q1	2	3	3
	med	3	4	4
	Q3	5	5	5
	max	10	10	10

Table 44 Mean, s.d. and five point summary of number of calves born to cows of 6 years and over, 7 years and over and 8 years and over, for March and June data

5.2.5.2 Entries and exits

Herds grow or shrink depending on the number of entries and exits, governed by external factors (weather, grazing availability, disease) and decisions deriving from factors internal to the household, such as household needs for cash. An investigation of herd dynamics was based on analysis of data from the June questionnaire, where each respondent from 40 selected households was asked for the number and type of cattle born or purchased over the previous year, and the number and type of cattle which died, was sold, was slaughtered or given away as a gift over the past year. To focus respondents on numbers over the previous 12 months, events of social importance such as Ramadan and the Eid el Fitr Salah (prayer) and seasons were used to define the beginning of the period of interest (June 2010). The survey was conducted at the beginning of the wet season, people were asked to recount entries and exits since the beginning of the last wet season (since the wet season began during approximately the same period in 2010). Data were collected on: price obtained at sale or purchase of cattle, reasons for sale or slaughter, gifting, death or purchase. Animals slaughtered for ill health were included in the death category (it

was assumed that they would have died). The majority of herd entries are from births (93%), household purchase of cattle purchases was rare (Table 45).

	Entries		Total entries
	Births	**Purchases**	
No. HH (%)	39/40 (97.5)	20/40 (50)	40/40 (100)
No. cattle	1070	76	1146
% contribution	93.4	6.6	100.0
mean No./HH	27.4	3.8	28.7
	Calving rate	**Purchase rate**	**Entry rate**
Denominator	Cows and heifers	All cattle	All cattle
Number cattle	2971	5722	5722
Rate (%)	36.0 (1070/2971)	1.3 (76/5722)	20.0 (1146/5722)

Table 45 Summary of number and rate of herd entries due to births and purchases for households sampled during June survey (rates based on herd size one year previous, see text)

Just over 50% of herd exits are due to off-take (sale, slaughter or giving or gifts), and just under 50% were due to mortality (Table 46). Forty-five % of animals are sold, and very few are slaughtered or given away as gifts. The mortality rate in calves is double that in animals over one year indicating that calf diseases and / or under-nutrition have a critical impact on herd productivity.

	Exits						Total exits
	Calf deaths	**Non-calf deaths**	**Sale**	**Slaughter**	**Gifts**	**Offtake**	
No. HH (%)	26/40 (65.0)	26/40 (65.0)	39/40 (97.5)	15/40 (37.5)	16/40 (40.0)	39/40 (97.5)	40/40 (100.0)
No. cattle	142	363	500	37	63	600	1105
% contribution	12.9	32.9	45.2	3.3	5.7	54.3	100.0
Mean No./HH	5.5	14.0	12.8	2.5	3.9	15.4	27.6
	Calf death rate	**Non-calves death rate**	**Sale rate**	**Slaughter rate**	**Gift rate**	**Offtake rate**	**Exit rate**
Denominator	Calves	Non-calves	All	All	All	All	All
No. cattle	1070	4652	5722	5722	5722	5722	5722
Rate (%)	13.3	7.8	8.7	0.6	1.1	10.5	19.3

Table 46 Summary of number and rate of herd exits due to calf deaths, adult deaths, sales, slaughter and gifts for households sampled during June survey

The number of households engaging in activity, mean number entering or exiting per household, and the 'rates' of exit and entry were calculated for each category. For most categories this was calculated as a percentage of the whole herd, but for calving rate and death rate the denominator was more specific (see below). Because these data relate to cattle entries and exits over the last one year, the herd size in June 2010 was calculated (i.e. one year previously) and the rates based on this herd size. The frequency distribution of rates for all categories has been illustrated in Figure 74. Boxplots of the average of each rate are also been plotted in Figure 75.

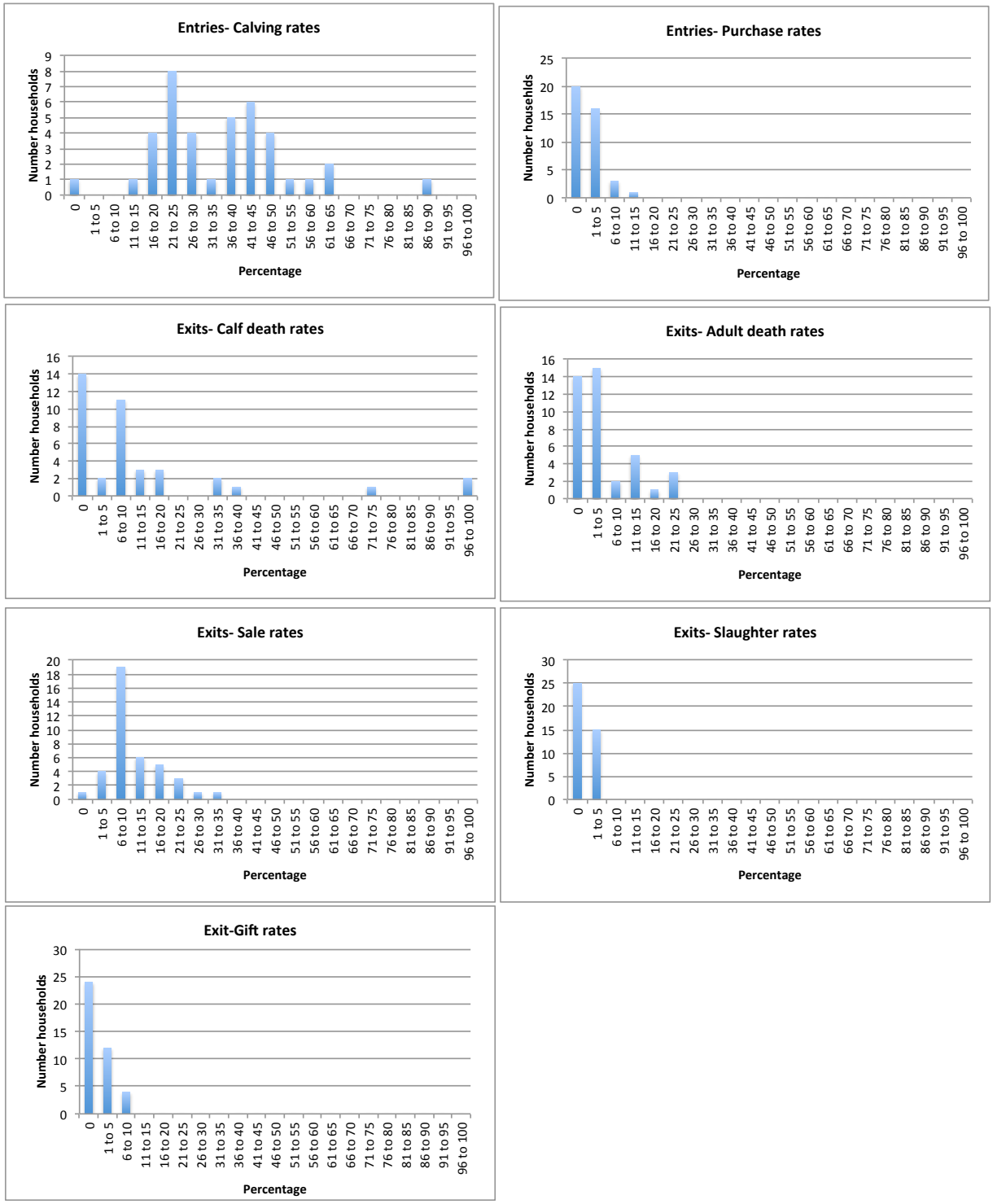


Figure 74 HH calving, purchase rates, calf death, adult death, sale, slaughter and gift rates

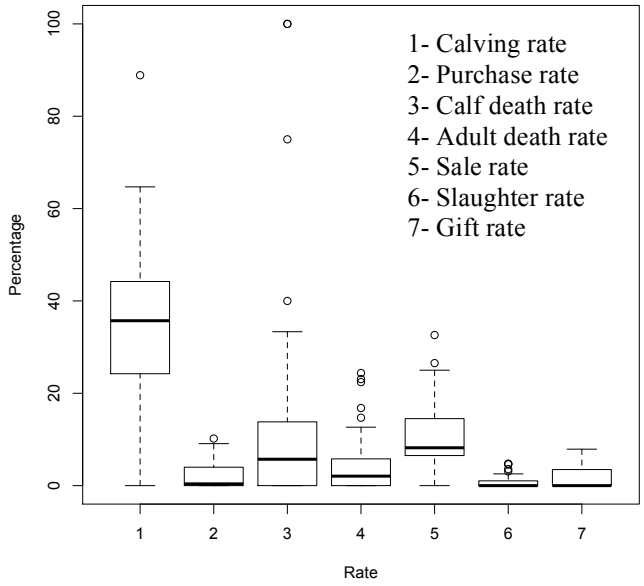


Figure 75 Boxplot of average calving rate, purchase rate, calf death rate, adult death rate, sale rate, slaughter rate and gift rate per household

Correlations between births, purchases, deaths and off-takes and their respective rates and TLU per capita, TLU per household, and herd size were explored for impact of household wealth on herd management decisions and dynamics (Table 47).

		TLU/ capita	*TLU/ HH*	*Herd size*		*TLU/ capita*	*TLU/ HH*	*Herd size*
No. births	R	0.164	0.948	0.971	Birth rate	-0.283	0.054	0.034
	p	0.325	0.000*	0.000*		0.085	0.743	0.836
No. purchases	R	0.259	0.149	0.14	Purchase rate	-0.031	-0.112	-0.102
	p	0.116	0.364	0.395		0.855	0.505	0.544
No. calf deaths	R	0.066	0.882	0.92	Calf death rate	-0.224	-0.054	-0.024
	p	0.695	0.000*	0.000*		0.183	0.746	0.887
No. non-calf deaths	R	0.086	0.868	0.92	Non-calf death rate	-0.12	0.074	0.109
	p	0.606	0.000*	0.000*		0.472	0.657	0.51
No. sales	R	0.225	0.904	0.945	Sale rate	-0.146	0.276	0.269
	p	0.174	0.000*	0.000*		0.389	0.094	0.102
No. slaughters	R	0.167	0.129	0.149	Slaughter rate	-0.09	-0.065	-0.067
	p	0.315	0.435	0.367		0.592	0.693	0.685
No. gifts	R	0.2	-0.021	-0.031	Gift rate	0.229	-0.083	-0.114
	p	0.229	0.891	0.853		0.166	0.615	0.49

Table 47 Results of Pearson's correlation between entry and exit numbers and entry and exit rates and measures of wealth (*statistically significant)

5.2.5.2.1 Births

Thirty-nine out of the 40 households reported births in their herds in the past year. The mean number of calves born per household was 27. One respondent declared he had had no calves born to a herd of 112 animals but individual animal data records for this household show calves of less than one year. Despite efforts to create the optimal conditions to discuss cattle numbers with household heads, this topic is taboo and data must be treated with caution.

The calving rate was calculated in relation to the total number of adult cows, and defined as the percentage of cows giving birth during one year out of the total number of sexually mature heifers and cows (females of 3 year or over) (Dahl and Hjort, 1976). A mean calving rate of 36% was calculated, which is similar to figures reported for the sub-humid zone of West Africa but low compared to populations of East Africa. A calving rate of 36% was reported for the Jos Plateau in the 1970s (Pullan, 1979). A calving rate of 54% was reported for Fulani herds in Kaduna in the 1970s (Otchere, 1982). Calving rates of 50%, 50% and 48% have been reported for Fulani herds in Southern Zaria, Mabila and Ganye respectively (Blench, 1984).

Calving rates for East African pastoralist herds under are reported between 50-90%; substantially greater than obtained in this study (Lane, 1991, Cossins and Upton, 1987, Homewood and Lewis, 1987, Dyson-Hudson and Dyson-Hudson, 1975, Leeuw et al., 1991, Homewood, 1992, McCabe, 1985, Sieff, 1995). This suggests that conditions in the KGR are suboptimal and are placing stress on cattle (Sieff, 1995). Low calving rates are usually associated with droughts causing dramatic drops in fertility rates (Dahl and Hjort, 1976, McCabe, 1985), but rainfall in the wet season of June 2010 in KGR was average. This low productivity could reflect the over-stocking and lack of grazing in the KGR. Including all female cattle 3 years and over to calculate calving rate may have impacted and a higher figure may have been obtained if only animals 4 years and over had been included. The paper by Amanor (1995) compares calving rate by ecological zone and reports that the lowest calving rates are found in the sub-humid zone, with higher calving rates (around 60%) in the arid and semi-arid zone. This would suggest that the low calving rate is normal for

the ecological zone and reflects the limitations of the environmental conditions (and also perhaps of cattle breed) rather than productivity limitations specific to KGR.

Figure 74 shows that there are two peak of calving rate, one at 21-25% and the other 41-45%. The mean calving rate is lower than that reported for nomadic herds by (Demiruren, 1974). The desired rate is 90% but 50-80% is normal for traditional pastoralism Williamson and Payne, 1965). A lower calving rate has been reported for sedentarised cattle and this could explain the two peaks: the lower corresponding to sedentary herds and the higher to transhumant herds (Hunting, 1974).

One respondent reported an 88% calving rate (Figure 74). In this herd, the 9 cows and heifers of reproductive age reportedly gave birth to 8 calves between them. This may reflect an unreliable response or be a very well managed and productive herd, or one or more of the females had twins, something exceptional but not impossible.

There is significant correlation between number of births and TLU per household and number of births and herd size. Larger herds have larger numbers of sexually mature females that results in more calves. There is no correlation between birth rate and measures of wealth (Table 47). Sieff (1995) also found no relationship between the reproductive rates of cattle and any measure of wealth, which was attributed to both wealthy and poor households having the same grazing regime. Adequate nutrition is a major factor for fertility. Since access to grazing is the same for poor and wealthy households, the reproduction rate is not higher in wealthier households.

5.2.5.2.2 Purchases

Half of the households (20 out of 40) had purchased cattle in the past year. Of those who bought cattle, the average number of cattle purchased per household was 4. Very few households reached a purchase rate of more than 5% (Figure 74). Households with a high purchase rate all had herds of less than 60 cattle. It would be expected that these households would be buying females to increase the productive capacity of their herds. We expected the data to show the purchase of more female than male cattle, but Table 48 shows that half of the purchases were for males. Most animals purchased were juveniles (for approx. 30,000 Naira, 170 USD). Fulani like to buy young males as breeding bulls to improve the genetic diversity of their herd,

which may explain the higher than expected number of males purchased. Note that calves were not purchased. There is no correlation between number or purchase rate and measures of wealth (Table 47).

Category	No. HH	No. cattle	%	Mean purchases/HH	Mean expenditure/cattle (Naira)
Male	17	40	52.6	2.4	
Juvenile	15	38	50.0	2.5	28,672
Mature	2	2	2.6	1.0	77,500
Female	16	36	47.4	2.3	
Juvenile	14	33	43.4	2.4	29,839
Mature	2	3	3.9	1.5	50,000
Total/Overall mean	***20***	***76***	***100.0***	***3.8***	***31,306***

Table 48 Number HH that purchased cattle in the last year, number and percentage of cattle purchased, mean number of cattle purchased/HH and mean expenditure per cattle

5.2.5.2.3 Calf mortality

Mortality is defined as the relative number of deceased animals during one year (Dahl and Hjort, 1976). Death rates fluctuate from year to year depending on climatic and disease conditions and this data is representative of June 2010 to 2011. Of the 505 overall deaths across all age groups, 142 (28.1%) of deaths correspond to calves. Twenty-six out of the 40 households reported death of calves over the past year. This is lower than the 48.7% previously reported by Sieff (1995) but the pervious study included calves from 0 to 24 months, whereas the estimate for KGR included calves under 12 months. The average number of calves lost per household was 6. Calf death rate was estimated by dividing the number of calves that died in the last one year by the total number of calves born in the last one year, which yields a reasonably accurate estimate when relying on cross-sectional data of this nature. The average calf mortality rate was 13%, similar to the 15% calf mortality figure reported by Williamson and Payne (1965) in their survey of North-Nigerian stock. Demiruren (1974) gives 10-15% as a common rate and Leeuw et al. (1991) 6-15%. Data for other East African pastoralist herds reveals slightly higher calf mortality rates: 39% (Lane, 1991), 25% (Cossins and Upton, 1987) and 26.7% (Sieff, 1995). Sieff (1995) used a different method to calculate mortality rate by diving the number of calves that die by the number of calves at the mid-point of the study, and included values of mortality rate of 200% in the overall analysis.

Although the vast majority of households experienced calf death rates of between 6-10%, a few lost 40%, 75% and even 100% of their calf crop, a huge loss from the productive potential perspective of their herds.

There is a significant correlation between both the number of calf deaths and TLU per household and number of calf deaths and herd size. There is no correlation between wealth and calf mortality (Table 47). This contradicts Sieff (1995) who found significantly lower calf mortality in wealthy households (wealthy households do not milk their cattle as hard as poor households, leaving more milk for the calves).

5.2.5.2.4 Adult and sub-adult mortality

Twenty-six out of 40 households experienced deaths in animals older than 1 year. The mean number of juvenile and adult cattle lost per household, for those households that reported losses was 14 cattle. The average mortality in adults (categorised as animals one year old or over) is 7.8%. This is similar to that reported by Meyn (1970) who reported losses in older animals in the order of 10%. Demiruren (1974) estimated mortality among cattle between one, two and three years old to be 7-8% and in those over four years old to be 5-7%. Other studies quoting adult mortality rates comparable to the values reported here for KGR include 9% (Lane, 1991); 6-11% (Homewood, 1992) and 11.7% (Sieff, 1995).

The mortality rate (calculated by dividing the number deaths by the herd size 1 year ago minus the number of calves) was 1-5% for most households. Some households experienced death rates of over 10%, These households were new settlers who attributed the loss of their cattle to the Kaduna crisis. A large number of cattle were slaughtered during the crisis with a large negative impact on herd productivity for these households reflecting the far-reaching impact of conflict on livelihoods.

The most common reason for cattle deaths was disease (63%); 21% ascribed to *Samore* (trypanosomiasis) and 12% for *Hanta* (liver fluke). Most respondents were unsure of the disease condition. Trauma accounted for 12% deaths, starvation 6% and 15% were killed during the crisis. One animal died of old age (Table 49).

Mortality rates were not available for each cattle class. Higher mortality rates in females are associated with demands of pregnancy and lactation (Sieff, 1995).

As was the case for deaths in calves, there is a correlation between both the number of adult or sub-adult deaths and TLU per household and adult and sub-adult deaths and herd size, as larger herds will proportionally have a higher number of deaths. There is no correlation between death rate and measures of wealth (Table 47).

Reason for death	**Number of responses**	**%**
Disease	21	63.6
Non-specified 'Sickness'	*10*	*30.3*
Samore	*7*	*21.2*
Hanta	*4*	*12.1*
Trauma	4	12.1
Fell in pit	*2*	*6.1*
Drowned in river	*1*	*3.0*
Accident during grazing	*1*	*3.0*
Starvation	2	6.1
Killed in violence during crisis	5	15.2
Old age	1	3.0
TOTAL	***33***	***100.0***

Table 49 Number of percentage of responses given for cause of death of animals

5.2.5.2.5 Sale

The decision of which animal to sell depends on factors such as size, species composition, age and sex structure and magnitude of cash need. Small cash needs are often met by selling small stock. Sale of cattle, however, is required for replenishment of grain stock (millet), weddings or other important festivities such as naming ceremonies (Sutter, 1987). Households usually prefer to sell the non-productive elements of their herds (cull cows, sterile heifers and non-breeding males). Sale of cattle does not always reflect economic health (Sieff, 1995), and often peak sales occur in times of destitution when households are forced to sell stock to buy food. High commercial off-take rates have been shown to be due to poverty and subsistence stress rather than increased commercialisation.

All households in KGR but one had sold cattle in the past year. The household that did not sell cattle had a herd size of 250 cattle. On average 13 cattle are sold per

household, higher than the 2 cattle per household per year reported by Awogbade (1983) in his study on the Jos Plateau. Note that calves were not sold.

The overall sale rate, calculated on total herd size as of one year previous to the survey, is 9%. Most households sell 6-10% of their stock a year. Three households sold over 20% of their stock. One of these households sold cattle to pay for a wedding, another was a new immigrant who sold cattle to build a new house, and another sold cattle to pay for cattle drugs (see Table 51). Most households sell cattle for everyday cash needs and for school fees. The category of animal most frequently sold consists of young males (30%), although 20% young females were also sold. Around 10-15% are breeding females, large adult males, small adult males and old females (Table 50). Average prices obtained for each animal in these categories are shown in Table 50. Economic incentives for herders to retain animals for as long as possible and market them in mature form would be advantageous (Sutter, 1987).

The sale of such a high percentage of female cattle and young males by KGR households may represent an increasing dependence on cash to survive since sale of reproductive female cattle is considered to diminish a herd's reproductive potential and the sale of young males and heifers results in lower financial returns than if pastoralists could keep these animals until they had reached maturity (Sieff, 1995).

Milk is the most important commodity forming the main pastoral market product of pastoralists of the sub-humid zone in Africa (Amanor, 1995). Productive female cattle are usually not sold by Fulani of the sub-humid zone until they attain their maximum weight. The data presented here show that KGR households focus on the breeding of young livestock for sale, a strategy associated with pastoralism in arid-areas (Amanor, 1995) and which could reflect the poor access to good grazing of the KGR community. Another possibility is that the lack of a market for milk has favoured a breeding strategy for rapid calf production for sale.

Agro-pastoralists are characterised by production of mature male fat stock and plough oxen, but more young animals were sold than large bulls, which suggests that the cash demands by KGR households are met by rapid calf production and sale at a young age. The overall cattle population included very few plough oxen, indicating that they do not play a large role in the household economy. Plough oxen are well

established in other areas of West Africa, such as the sub-Sahelian cotton growing zones including those of northern Nigeria (Starkey and Faye, 1990, Blench, 1997).

The data presented here for KGR aligns with studies undertaken in the arid-zone of West Africa, including a study in Fulani communities in Niger and Senegal, where sales consisted of 30-40% of male calves under 3 and 20% of females calves under 4 (White, 1989, Sutter, 1987). Fricke (1979) shows that the tendency is for sale of older males in Northern Nigeria. The data from KGR shows that males account only for 53% of KGR sales, much lower than the 70-80% figure for males found for trade cattle studies in Jos, Kano and Kaduna. The figure from KGR is more in line with the 48% sale of females found for studies in the arid-zone (data for which is described as being symptomatic of failure to recover from the drought of the 1970s (White, 1989)). This would, suggest, therefore that a perturbation of the KGR system, (e.g. years of climatic instability, unreliable duration of wet seasons and poor access to grazing) has affected herd productivity enough to impact on herd structures which is reflected in commercial habits of households.

In the absence of climatic data which would support this, it is likely that the Fulani of the KGR have developed a breeding strategy which focuses on the breeding of heifers for sale and of males as fat-stock but in which milk is not an important cash resource. This has been described as '*a variant of specialised milking strategies*' (Amanor, 1995): the example of a study undertaken by Fricke (1979) is cited where the majority of stock are sold young, between the ages of 2 and 3, with up to 15% of total sales consisting of heifers. The isolation of KGR from other non-pastoralist communities, and responses during FDG indicate only a small market for dairy products, due to the distance to be travelled on foot to sell these products.

There is a significant correlation between the number of sales and TLU per household and number of sales and herd size. There is no correlation between sale rate and measures of wealth (Table 47), as found by (Sieff, 1995) who reported lower commercial off-take rates in wealthy households, due to the ability to sell bigger bulls for higher prices. Sutter (1987) also reported a direct relationship between herd size and percentage of males sold and age of animal sold, and more specifically that

poorer households had a tendency to sell more females and younger animals. The data presented here does not reflect such a trend.

Sale category of animal	No. cattle	% of cattle sold	No. HH	Mean cattle sold/HH	Mean sale price/animal (Naira)
FEMALES	***234***	***46.8***			
Young female	93	18.6	19	4.9	44,711
Breeding female	62	12.4	15	4.1	53,300
Old female	79	15.8	17	4.6	47,059
MALES	***266***	***53.2***			
Young male	151	30.2	30	5.0	47,789
Large adult males	52	10.4	11	4.7	78,273
Small adult males	63	12.6	12	5.3	53,875
Total cattle/overall mean	***500***	***100***	***39***	***12.8***	***663,096***

Table 50 Number of cattle sold per age/sex category, percentage contribution of different lifestages to overall sale total, number of households that sold cattle, mean number of cattle sold per household and mean sale price for each animal sold (for HH that sell cattle only)

Reason for sale	Overall	%
Old animal	1	1.3
Hajj	1	1.3
Naming ceremony	2	2.6
Move to KGR	2	2.6
Health/Hospital fees	3	3.9
Sick animal	3	3.9
Building	3	3.9
Food	5	6.6
Animal drugs	6	7.9
Marriage	7	9.2
School fees	17	22.4
HH cash needs	26	34.2
TOTAL	***76***	***100.0***

Table 51 Number and percentage of responses given for reason for sale of cattle

5.2.5.2.6 Slaughter

As stated in a FGD about meat consumption: "*KGR Fulani do not have much of a taste for meat"* and this is reflected in the low slaughter rate (0.6%). Only 15 out of the 40 households slaughtered animals and on average those that did killed 2.5 cattle per household. The maximum slaughter rate was 5% (3 households), the reasons for slaughter being for a wedding ceremony, for home consumption and for the Eid.

'Naming ceremonies' were the most common reason given for slaughter (Table 53). Most (73%) animals slaughtered were young males (Table 52). Large bulls generate too much meat that would spoil before the household could consume the whole animal. There is no correlation between measures of wealth and number of slaughters (Table 47).

Category	No. cattle	%	N HH	No. cattle/HH
Old female	2	5.4	1	2
Castrated bull	4	10.8	4	1
Entire bull	1	2.7	1	1
Cow	3	8.1	3	1
Young male	27	73.0	10	2.7
Young female	0	0.0	0	0
TOTAL	37	100	19	1.9

Table 52 Number and percentage of cattle slaughtered from each age/sex category, number of households that slaughtered cattle and mean number of cattle slaughtered per household (for HH that slaughter cattle only)

Reason for slaughter	No. responses	%
Marriage	3	15.0
Eid/Salah	4	20.0
Home consumption	6	30.0
Naming ceremony	7	35.0
TOTAL	20	100.0

Table 53 Number and percentage of responses given for reason to slaughter for cattle reported to have been slaughtered

5.2.5.2.7 Gifts

Giving of gifts to the needy for Zakat (alms-giving) is a customary Muslim tradition. The Fulani interpretation of the tradition is for one young male or female cattle to be given to a household in need for every 40 adult cattle owned. Sixteen households out of the 40 engage in gift giving, but the number of animals given as gifts for Zakat does not consistently follow the rule, with some households giving more cattle (and others less) than their herd size should dictate.

On average, households engaging in gift giving gave 4 animals per household, the majority gifting young males (although 37% gifted young females and 5% gave breeding females) (Table 54). The percentage 'gift rate' is 1%, approximately double that of the slaughter rate for all households which shows the importance of reciprocal

assistance and mutual aid in pastoralist communities. There are a few households for which the gift rate exceeds 5%. These households report giving animals away for Zakat but also gave gifts to relatives for assistance. One respondent explained giving away cattle to a relative who had lost all his cattle.

Zakat is the donation of cattle to non-family members at designated times of year, whereas gift giving to family members is practiced anytime to help the member of a kinship group in need of assistance. Zakat accounts for over 70% of all gift giving, and gifts to relatives for 25%. One respondent also described giving cattle away to assist the new immigrants affected by the crisis (Table 55).

The data show that active solidarity and reciprocal assistance, described as a key component for survival of pastoral communities, are still practiced in the agro-pastoralist community of KGR. That not all households chose to engage in Zakat may indicate that diversification into agriculture has pushed households towards individualistic behaviour (Bonfiglioli, 1993).

There is no correlation between measures of wealth and number or rate of gift giving (Table 47).

Category	No. cattle	%	No. HH	Cattle/HH
Young female	23	36.5	9	2.6
Young male	37	58.7	15	2.5
Breeding female	3	4.8	1	3.0
TOTAL	63	100	25	2.5

Table 54 Number and percentage of cattle given away as gifts, number of households undertaking gift giving and number of cattle given as gifts per household (for HH that engage in gift giving)

Reason for gift	No. responses	%
Zakat	15	71.4
Gift for a relative	5	23.8
Crisis aid	1	4.8
TOTAL	21	100

Table 55 Number and percentage of responses given for reasons to give cattle away as gifts, for cattle reported to be given away as a gift

5.2.5.3 Offtake rate

The off-take rate is the combination of herd exits due to cattle sales, slaughter and gift giving. The three have been combined to compare values in this study (10.5%) with others. These range from 5% (Lane, 1991) to 20% (Sieff, 1995) and 10% (Homewood, 1992) for East African pastoralists. Off-take rates in W. African Zebu are between 11 and 13% (Sutter, 1987, FAO, 1976, Shapiro, 1979, UNESCO, 1981).

5.2.5.4 Net change in livestock holding

The net change in herd size (HS) between 2010 -2011 was calculated as:

HS one year ago = Current HS – entries + exits
% change (inc/dec) in HS = (Current HS – HS one year ago)/HS one year ago x 100

Most households sampled during June 2011 experienced a herd growth rate of 1-10% (Figure 76). Overall the average household had 1 animal more in June 2011 than in June 2010. A substantial number lost more animals than they gained, and saw their herd size reduce by 1 to 20%. One household, experienced a herd size reduction of 54%, losing 10 adults and all calves (5 calves born in 2010 all died), and reported having to sell 5 animals. The herd reduced from 46 down to 21 heads. Overall the productivity of cattle rearing in KGR is such that the cattle owned by the 40 households sampled increased by 0.7% (5722 in June 2010 to 5763 in June 2011). Most households in KGR are managing to maintain current wealth productivity and herd growth rates remaining low).

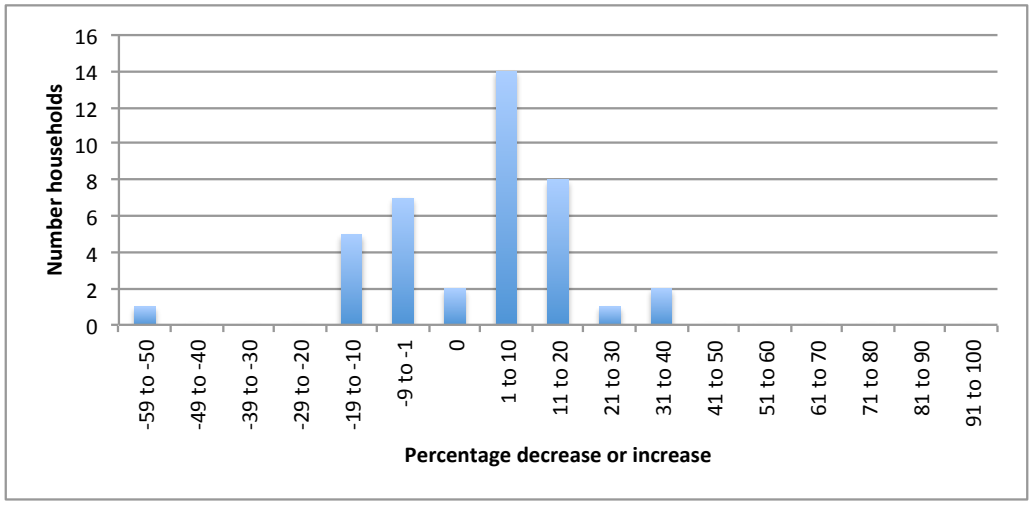


Figure 76 Frequency distribution of percentage decrease/increase in herd size over 1 year period

5.3 Conclusion

Transhumance, herd composition and herd productivity have been found to be differ from other pastoralist systems in the following aspects:

- Some households selected a sub-sample of animals for transhumance rather than sending the whole herd;
- Mass immigration into the KGR and the ensuing increase in cattle population encouraged transhumance both during the dry and wet seasons. Wet season migration was undertaken predominantly by new settlers;
- The selling of heifers is an unusual finding which goes against the 'cattle complex' theory and indicates that people in the KGR are limiting their herd size voluntarily as well as limiting milk production. This may be due to the absence of a milk market and a higher reliance on sale of young stock to meet cash needs.

The triangulation approach ensured that reliable cattle numbers were obtained. The underestimates and overestimates in cattle numbers yielded by some approaches (census and deworming counts respectively) highlights the difficulties in obtaining accurate data in this setting.

6 Chapter 6 Brucellosis review

6.1 Background on brucellosis

Brucellosis is the collective name for animal and human infections caused by several species of the genus *Brucella*. Brucellosis is one of the most widespread zoonoses in the world (World Health Organisation, the Food and Agricultural Organisation and the World Organisation for Animal Health (WHO, 2005, FAO, 2003, OIE, 2009a, OIE, 2009b, Okello et al., 2011). The International Livestock Research Institute considers brucellosis the most important zoonosis (Perry et al., 2002).

The disease is endemic in many parts of the world including the Mediterranean region, Asia, the Middle East, Latin America and Africa. It is a worldwide re-emerging disease (Alvarez et al., 2011, Ebright et al., 2003, Godfroid et al., 2005b, Gwida et al., 2010, Mailles et al., 2012, Manosuthi et al., 2004, Mantur and Amarnath, 2008, Robson et al., 1993, Russo et al., 2009, Shimshony, 1997, Tsou and Mu, 2012, Van Bressem et al., 2009, Wallis, 1977), causing severe human disease and high economic losses in livestock (Godfroid et al., 2005a, Pappas et al., 2006).

The burden of brucellosis in Africa in poorly documented, with only scant data available in humans and animals (Dean et al., 2012, Ducrotoy et al., 2014, Okello et al., 2014, McDermott and Arimi, 2002, ILRI, 2012). It is generally assumed that the disease is grossly under-reported (Cadmus et al., 2009, Dean et al., 2012), especially in humans, as diagnosis is challenging and its 'protean' non-specific, insidious presentation is often falsely attributed to malaria, which is perceived by health professionals as being much more prevalent (Zinsstag et al., 2011b). For each case diagnosed, it is estimated that four are undetected as clinical signs are ignored or mistaken as 'other infectious diseases' (Pappas et al., 2006).

In livestock herds, presence of disease will cause abortion, infertility (female and male) and reduced milk yields, representing a substantial financial burden to livestock keepers. The flu-like disease of fever (undulant or not), weakness, malaise, myalgia and weight loss in humans, despite not having a high mortality rate, is debilitating, often chronic and insidious, and constitutes a significant disability to those affected. Brucellosis can also result in serious complications, including

endocarditis, musculoskeletal lesions (e.g. spondylitis) and neurobrucellosis, the former with a very high mortality rate. Severe acute infections can be fatal but brucellosis is more often a chronic condition (Zinsstag et al., 2011b). The occurrence of disease in humans is a direct reflection of the situation in animals. Close proximity with infected livestock is a risk factor for acquisition of disease, and therefore working with livestock and livestock products constitutes an occupational hazard.

6.1.1 Historical perspectives

Historically, the human disease was repeatedly described in the Mediterranean basin under different names (Gibraltar fever, Cyprus fever, Napolitan fever, intermittent typhoid fever, typho-malarial fever, undulant fever, Mediterranean fever, and Malta fever). In the 19th century, British physicians investigated the disease because of its devastating consequences in the garrison at Malta (75,000 days of sickness per year in for a force of 25000). Bruce first isolated the microorganism from the spleen of dead serviceman in 1887 but the infection could not be traced to human-to-human contagion despite intensive research (Vassallo, 1996). The reservoir remained a mystery until Zammit and Horrock found the connection with goat milk in 1894, and demonstrated the infection in apparently healthy goats in 1905 (Vassallo, 1996, Wyatt, 2005). The Mediterranean Fever Commission (formed in 1904) prohibited goat milk consumption in the Navy and the Army in 1905 and in only two years the number of human cases dropped from 913 (23 deaths) to 21 (1 death) whereas it persisted in civilians (663 and 714 cases with 88 and 78 deaths). In 1897, Bang isolated brucellae from the uterus of a cow that was aborting and also observed the presence of the bacterium in very large numbers within cells of uterine exudates (hence the name contagious abortion or Bang's disease) (Mochmann and Kohler, 1988). Later work identified brucellosis in domestic swine in Europe and the USA.

The connection between contagious abortion of cattle and the Malta fever agent was not formally established until 1920 when the genus *Brucella* was defined (Mochmann and Kohler, 1988, Evans, 1918, Meyer and Shaw, 1920). *B. suis* was recognized as an entity different from *B. abortus* in 1929 (Huddleson, 1929). Since then, other *Brucella* species have been added to the genus and the range of hosts expanded to include not only domestic ruminants and swine but also a wide range of

mammals (Stoenner and Lackman, 1957, Buddle, 1956, Jones et al., 1968, Foster et al., 2007a, Scholz et al., 2008, Carmichael and Bruner, 1968). Species classification has been controversial and has undergone changes over time (Box 3). The classical species system is coherent with both preferential host range and detailed molecular analyses for all species except *B. suis* and the closely related *B. canis* (Diaz et al., 1967, Diaz et al., 1968, Hoyer and McCullough, 1968, Verger et al., 1985, Moreno et al., 2002, Osterman and Moriyón, 2006, Al Dahouk et al., 2005, Chain et al., 2005, Foster et al., 2007b, Foster et al., 2009, Le Fléche et al., 2006, Scott et al., 2007, Vizcaíno and Cloeckaert., 2004, Whatmore et al., 2005, Whatmore et al., 2007a).

6.1.2 The aetiologic agent

BOX 3- Species classification over time

1887 – Bruce isolates *Micrococcus melitensis* from a human case in Malta
1897 – Bang isolates *Bacterium abortus* from uterus of aborting cow
1904 – Zammit and Horrock make connection with human brucellosis and consumption of goat's milk
1918 – Evans demonstrates close relationship of *M. melitensis* and *B. abortus*
1920 – Based on Evan's recommendations, Meyer and Shaw propose genus *Brucella*
1929 – Huddleson proposes species *B. suis* as replacement of atypical *B. abortus* strain classification
1957 – Description of *B. neotomae*
1956 – *B. ovis* added to *Brucella* genus
1968 - *B. canis* added to *Brucella* genus
1985 – Because all brucellae display >90% DNA:DNA hybridisation rates (which is inconsistent with definition of distinct genemospecies which requires rate >70%) previous classification challenged by Verger et al and a single species proposed (*B. melitensis* of which the others would be biovars)
2006 – Concept of 'biological species' favoured for classification and return to classical species approved by *Brucella* Taxonomy Subcommittee as more coherent with preferential host range and detailed molecular analyses
2007 – *Brucella ceti* & *Brucella pinnipedialis* proposed as species
2008 – *B. microti* isolated from common vole

The three *Brucella* species of major concern with regards to human health and livestock productivity include:

1. *B. abortus* (biovars 1-9) primarily affects cattle, other bovidae and cervidae
2. *B. melitensis* (biovars 1-3) primarily affects sheep and goats
3. *B. suis* (biovars 1-5) primarily affects swine and a variety of other wild mammals.

The other brucellae comprise:

1. *B. ovis*: causes ram infectious epididymitis (not zoonotic)
2. *B. canis*: causes abortion in dogs
3. *B. neotomae*: found in desert woodrats in the Western United States
4. *B. pinnipediae*: one of the marine brucellae, affecting seals and otters
5. *B. ceti*: one of the marine brucellae, affecting porpoises and whales
6. *B. microti*: found in common voles
7. *B. inopinata*: isolated from a human case (prosthetic breast implant infection)

Brucella species have a strong host preference but are not host-specific. All species can affect a wide range of animals, including humans, although not all species are zoonotic and human pathogenicity varies for species and biovars (Table 56).

Species	Biovars	Geographic distribution	Major host	Human pathogenicity
Classical species				
B. abortus	1-6 (7), 91	Ubiquitous	Cattle (including domestic livestock and wild ungulates)	Moderate
B. melitensis	1-3	Mediterranean basin, Middle	Sheep and goats	High
B. suis	1 and 3	America, Asia and Oceania	Swine	High
B. suis	2	Central and eastern Europe	Swine and hares	Low
B. suis	4	Alaska and Russia	Reindeer	Moderate
B. suis	5	Russia	Wild rodents	Not known
B. canis	None	Ubiquitous, high prevalence in South America	Dogs	Low
B. ovis	None	Mediterranean basin	Sheep	Nil
B. neotomae	None	Utah (USA)	Woodrats	Not known
Newly described species				
B. cetaceae	None	Not known	Porpoises, dolphins and whales	Recent case reports describing some human cases (mainly neurobrucellosis)
B. pinnipediae	None	Not known	Seals and otters	Recent case reports describing some human cases (mainly neurobrucellosis)
B. microti	None	Not known	Common vole	Not known
B. inopinata	None	Not known	Not known	Isolated from infected human breast implant

Table 56 The different *Brucella* spp. and their respective biovars, geographic distribution, major host and human pathogenicity
(Source: Maurin, 2005, Pappas, 2010, Whatmore, 2009)
[1] The status of biovar 7 is under review as the reference strain is believed to represent a mixed culture. Biovar 8 was suspended by the Subcommittee on the Taxonomy of the Genus *Brucella* in 1978 (Corbel and Banai, 2005).

6.1.2.1 Antigenic composition and pathogenesis

The lipopolysaccharide (LPS) component of *Brucella* spp. outer membranes is associated with virulence and the LPS antigen that dominates the antibody response. The LPS is characterised into 2 types: rough and smooth. The two classifications are abbreviated to S-LPS and R-LPS and relate to the presence or absence, respectively, of an O-polysaccharide or O-chain. The commonly identified human pathogens, *B. abortus*, *B. melitensis* and *B. suis* are described as smooth because S-LPS is present in their outer membranes. But for *B. ovis* and *B. canis*, the remaining species also carry S-LPS. *B. ovis* and *B. canis* are described as non-smooth or R as they express no O-polysaccharide in their LPS. The similarity in the LPS O-antigen composition of *Brucella* species and some *Escherichia hermanni* strains, *Escherichia coli* O:157, *Samonella* O:30, *Stenotrophomonas maltophilia*, *Vibrio cholera* O:1 and *Yersinia enterocolitica* O:9 is responsible for the antigenic cross-reactivity observed during serological testing (Perry and Bundle, 1990, Douglas and Palmer, 1988).

Other antigens recognised by the immune system during infection and therefore of potential use in diagnostic testing include various outer and inner membrane, cytoplasmic and periplasmic protein antigens (Cloeckaert et al., 2002, Salhi et al., 2003, Tibor et al., 1999, Velasco et al., 1997). Thus far these antigens have shown limited diagnostic usefulness, as the immune response triggered is less consistent than that to LPS. These proteins lack the serological cross-reactivity with the above-mentioned bacteria, and can therefore be used to distinguish infections caused by *Brucella* from those caused by bacteria cross-reacting at the S-LPS level (Letesson et al., 1997, Cloeckaert et al., 1992). The topological, molecular and supramolecular properties of *Brucella* antigens are discussed in more detail in Chapter 7.

The nature of *Brucella* pathogenesis in natural host species and humans remains incomplete. Not all virulence factors are known and, for those that are, the cellular targets they interact or interfere with need to be clarified. *Brucella* is a facultative intracellular pathogen, invading both non-phagocytic and phagocytic cells. The mechanism for cell adhesion and invasion remains unconfirmed. Brucellae are well adapted to reach privileged sites where they can undergo multiplication with minimal disturbance to the innate immune system. Within non-phagocytic cells, brucellae

localise in the endoplasmic reticulum (Celli and Gorvel, 2004). In phagocytic cells, the S-LPS plays a major role in intracellular survival (Lapaque et al., 2005).

Bactericidal responses are inefficiently triggered at early infection due to modified pathogen associated molecular patterns of the envelope components, barely detected by innate immunity receptors. This leads to a low and delayed cytokine response and poor dendritic cell and macrophage activation that allows the pathogen to reach the replicative niche (Barquero-Calvo et al., 2007). In addition, a type IV VirB secretion system (Marchesini et al., 2011) and the activity of periplasmic glucans (Arellano-Reynoso et al., 2005) are involved. During the intracellular phase, brucellae survival within macrophages is dependent on programmed expression of various genes under the control of quorum-sensing and two-components sensory and regulatory systems (Delrue et al., 2005, Viadas et al., 2010), some of which are induced by the acid macrophage intracellular environment. The pathogenic role of iron-sequestering proteins or other siderophores remains uncertain (Corbel, 1997, Enright, 1990).

6.1.2.2 Bacteriology

Most brucellae are gram-negative coccobacilli or short rods of 0.5–0.7 by 0.6–1.5 μm (some strains produce larger cells) arranged most often individually, non-motile and without capsules. They stain positive in Stamp's modification of the Ziehl-Neelsen method for acid-fast bacteria. Combinations of peptones, yeast extract and glucose such as those in several blood-agar base or tryptone-soya basal media or in Albimi medium are good media to grow most brucellae. On primary isolation most strains show retarded growth in media devoid of blood or serum. *B. ovis* and some *B. abortus* strains strictly require serum and 5-10% CO_2. Colonies have an entire edge and are transparent, convex and small (0.5–1.0 mm after 2–3 days of incubation) but there are variations depending on the medium and strain. With obliquely reflected light, the S colonies appear moist, glistening, and bluish, whereas the R colonies have a dry, granular aspect. Other features are the lack of fermentative metabolism or haemolysis. All *Brucella* species are catalase positive, all but *B. ovis* and *B. neotomae*, are cytochrome *c*-oxidase positive, and all but *B. ovis* reduce nitrate to nitrite and show variable urease activity. Since cross-reacting bacteria are easily differentiated using simple bacteriological tests, slide agglutination with

antisera to S brucellae readily identifies S brucellae but not the R forms. Agglutination with acriflavine and the crystal violet-exclusion test performed on colonies allow differentiation of S and R brucellae (Alton et al., 1988).

Classical species identification requires experience, specific anti-A and anti-M sera and phages that have to be produced/maintained in the laboratory, and dye sensitivity assays. Classical typing at biovar level is similarly difficult and poses reproducibility problems so that it has to be performed by reference laboratories. Identification of the vaccine strains is a common need as vaccinated animals may shed them, and classical methods are based on penicillin, streptomycin, rifampin, dye and erythritol sensitivity, and on the S or R phenotype (Alton et al., 1988). Molecular tests advantageously substitute for the classical methods in species, vaccine, and in some cases, biovar typing. Methods like Bruce-ladder for species identification and VNTR for finer analyses are rapidly replacing classical methods and can be applied to colonies on isolation plates, thus avoiding dangerous manipulations.

6.1.3 Mode of transmission

6.1.3.1 Animal to human and human to human transmission

Transmission of infection to humans occurs through direct contact with infected animal tissues, blood, urine, vaginal discharges, aborted foetuses or placentas via breaks in skin or through inhalation. Indirect food-borne infections occur following ingestion of raw milk and other un-pasteurised dairy products (but rarely from eating the meat of infected animals because of the localization of the pathogen in the reticuloendothelial system). Occupational exposure, affecting abattoir workers, veterinarians, herdsmen and laboratory staff occurs through inhalation or mucosal exposure to aerosolised bacteria and is the main source of infection. Consumption of contaminated unpasteurized dairy products and occupational contact are the major sources of infection (Corbel et al., 2006, Zinsstag et al., 2011b). Human brucellosis is almost always the result of animal brucellosis. Human-to-human transmission is rare, although in-utero and sexual transmission has been reported (Corbel, 1997). Human-to-human contagion plays no role in the disease epidemiology.

6.1.3.2 Animal to animal transmission

Herds are exposed following introduction of an infected animal that subsequently gives birth or aborts, thereby causing contamination of pasture or water by the heavily infected discharges (placenta, fetal fluids, vaginal discharges) (Alton, 1990, Crawford et al., 1990). The route of exposure is thought to be through ingestion of contaminated fomites (contaminated equipment, feedstuffs, stalls, premises etc.), licking of tissues and aborted foetuses or inhalation. Vertical transmission from dam to calf can occur congenitally at least for *B. abortus* and *B. melitensis*. In such cases the disease remains latent without inducing detectable antibody responses until the first pregnancy (Grilló et al., 1997, Plommet, 1977). Infected females excrete the bacteria in milk and transmission to calves can also occur through this route. Veneral routes of transmission may be more common for rough strains (e.g. *B. ovis, B. canis*, *B. suis*), but this is a recognised route of transmission for smooth strains.

6.1.4 The disease

6.1.4.1 Human brucellosis

The clinical manifestations of human brucellosis are highly variable, most often unspecific and overlapping with those of other febrile conditions, including typhoid and malaria. In general, *B. melitensis* causes a more severe disease, followed by *B. suis* and then *B. abortus*. Persons who develop acute, symptomatic brucellosis may manifest a wide spectrum of symptoms including fever (undulant or not), sweats, malaise, anorexia, headaches, backache, arthralgias, myalgias, and weight loss. Lymphadenopathy, splenomegaly, and hepatomegaly are found in some cases. Apart from abscesses, complications include spondylitis, sacroiliitis, osteomyelitis, meningitis and orchitis. Endocarditis is the main cause of mortality (up to 3% of untreated cases). Abortion, premature delivery and intrauterine infection with fetal death have also been described (Zinsstag et al., 2011b).

Treatment is essential and the most important factor in poor outcomes is probably the delay in effective antibiotic treatment. Adults with acute brucellosis and no complications or focal disease should be treated as outpatients with doxycycline-streptomycin or doxycycline- gentamicin. Alternative regimes, necessary when tetracyclines are contraindicated, are less satisfactory. In focal forms, the preferred

regimen is the same as for uncomplicated brucellosis but duration must be extended and individualized. Surgery should be considered for patients with endocarditis, cerebral, epidural, spleen, hepatic or other abscesses not resolved with antibiotherapy. During pregnancy, tetracyclines and streptomycin must be avoided and a rifampin monotherapy is considered the regimen of choice. Trimethoprim-sulfamethoxazole (cotrimoxazole) plus rifampin is an alternative regimen but it can be teratogenic if used before week 13, and induce kernicterus after week 36. Children often have milder symptoms than adults. Since tetracyclines are generally contraindicated for children less than 8 years old, rifampin-cotrimoxazole is recommended. Alternatively, rifampin or cotrimoxazole plus gentamicin can be used. Some studies reported good results with long (>6 months) cotrimoxazole treatment. Depending upon the therapy, relapses occur in 5 to 30% of patients, usually 1 to 6 months after treatment and tend to be milder than the original attack. The bacteria isolated from relapses maintain the same antibiotic-susceptibility. Thus, nearly all relapses respond to a repeated course of therapy (Ariza et al., 2007).

For aspects of diagnosis in humans refer to Chapter 7.

6.1.4.2 Animal brucellosis

Brucellosis is a stealthy disease and at least *B. abortus* and *B. melitensis* escape early detection by innate immunity before they reach their replicative niche, an endoplasmic reticulum-derived vacuole of macrophages and dendritic cells but also a variety of non-phagocytic cells. Because innate immunity bolsters the initial steps of adaptive immunity, the cellular and antibody responses typically triggered by brucellae develop too late and are not effective to control multiplication in animals that had had no previous contact with *Brucella*. Most commonly, the port of entry in ruminants is the head mucosae and colonization of the head lymph nodes an early event. From these, the brucellae spread through the lymphatics and blood and colonize spleen, mammary lymph nodes, uterus, male genital organs, joint capsules and bursae. Then, genital and milk excretion occur, facilitating the transmission to other animals. Typically, the infection is asymptomatic in females until the first pregnancy when colonization of the placenta and extensive multiplication leads to abortions in the last third period of pregnancy and stillbirths. Thus, in

immunologically naïve herds or flocks the disease extends rapidly and "abortion storms" occur. Then, even though fertility may be compromised, abortions and stillbirths become progressively fewer (provided no new animals are introduced) possibly because of the establishment of a stalemate between the bacteria and immunity in animals that have undergone abortions, and the disease becomes "chronic" in some animals whereas others may recover. Not all animals in chronically infected herds/flocks show an immunological response detectable in immunological tests either because of congenital transmission, age, or other factors. Even though the individual prevalence detected in immunological tests can be relatively low, the herd/flock remains infected and is a constant source of animal and human contagion. What matters in brucellosis is not the individual but the collective (herd/flock) prevalence. This concept is key for surveillance, control and eradication. For aspects of diagnosis and control in ruminants see Chapters 7 and 10.

6.1.5 Overview of global epidemiology

Brucellosis is a multi-specie and non-host specific disease, resulting in a complex epidemiology in areas of endemicity. Occurrence of disease will vary from country-to-country and region-to-region depending on the pervading livestock production system, circulating strain of *Brucella,* human socio-economic factors, (such as the practice of consumption of non-pasteurised milk and fresh dairy products), occurrence of high risk occupational exposure to contaminated animal tissues, and encroachment of people and their livestock into wildlife areas of infectious potential (Mick et al., 2014). As a general rule, the magnitude of occurrence of disease in humans reflects the situation in livestock populations, as infected animals and their products are the sole reservoir and source of infection for human disease.

6.1.5.1 Epidemiology of animal brucellosis

Bovine brucellosis caused by *B. abortus* remains the most widespread form of brucellosis worldwide (Figure 77). *B. melitensis* has a more limited geographic distribution that follows the distribution of extensively bred sheep and goats and is thus problematic in the Mediterranean region, western, central and northern Asia, and parts of Africa and Latin America, and also periodically re-emerges in

previously disease free areas (Figure 78). Goat and sheep brucellosis (*B. melitensis)* causes the most severe and clinically apparent form of the disease in humans.

Small ruminants and cattle, and also camels, horses, buffaloes or yacks, are often reared together or come into contact in villages, drinking wells, etc. Under these conditions, cross-infections among these various hosts are very frequent. It is well known that *B. melitensis* is a cause of cattle brucellosis wherever control and eradication in sheep, goats and cattle have not been integrated into a single program (Verger, 1985). *B. suis* biovars infecting primarily pigs are also a cause of cattle brucellosis in some countries but there is a paucity of data on the inter-species transmissibility and persistence of other *Brucella* spp. in other potential hosts.

The disease caused by S *Brucella* species has been identified and antibodies reported in a variety of farm livestock other than ruminants, including horses, dogs, cats and fowl but these animals are more sentinels of the disease than active participants in its perpetuation. Brucellosis in wildlife is a complex and not well-known aspect of the disease. Although in most cases it is a spill-over disease, it can become permanently established in some animals that act as reservoirs (Zheludkov and Tsirelson, 2010).

Brucellae cannot multiply outside the host, even though they may survive in contaminated materials such as manure, products of abortions, etc. for some time, even months, depending on the conditions (Corbel et al., 2006). Dryness, high temperatures and sunlight are very unfavorable.

B. suis infections in domestic pigs are widespread but considered to be of overall low prevalence, except in South America and SE Asia where the prevalence is higher. Porcine brucellosis has become established in populations of wild and feral porcine species: *B. suis* biovar 1 in Latin America and Australasia, *B. suis* biovar 2 in central and eastern Europe and *B. suis* biovar 3 in the USA and China (Maurin, 2005).

Eradication campaigns have successfully achieved a bovine brucellosis-free status in Australia, Canada, Belgium, Denmark, Finland, France, Germany, the Netherlands, New Zealand, Norway, Sweden, the USA and the United Kingdom (Figure 77).

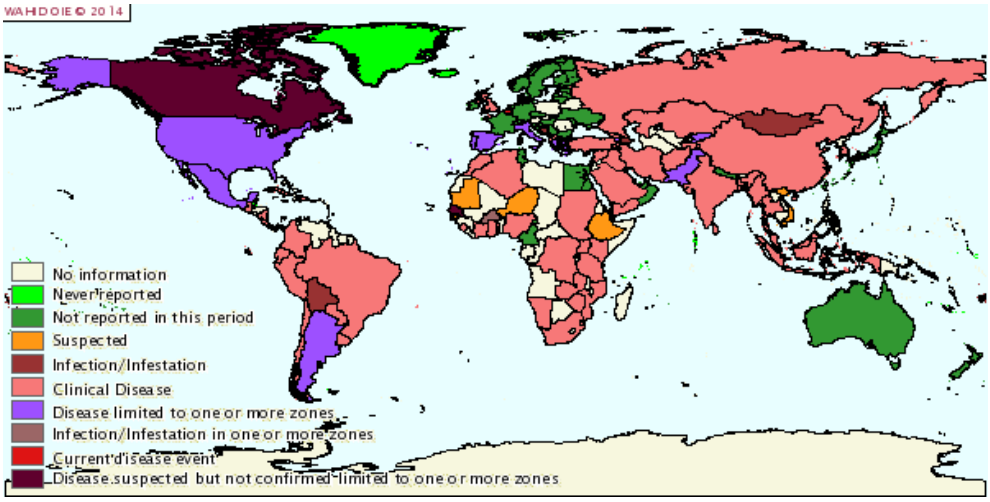


Figure 77 Disease distribution map: *Brucella abortus*, Jan-Jun 2013 (WAHID, 2014)

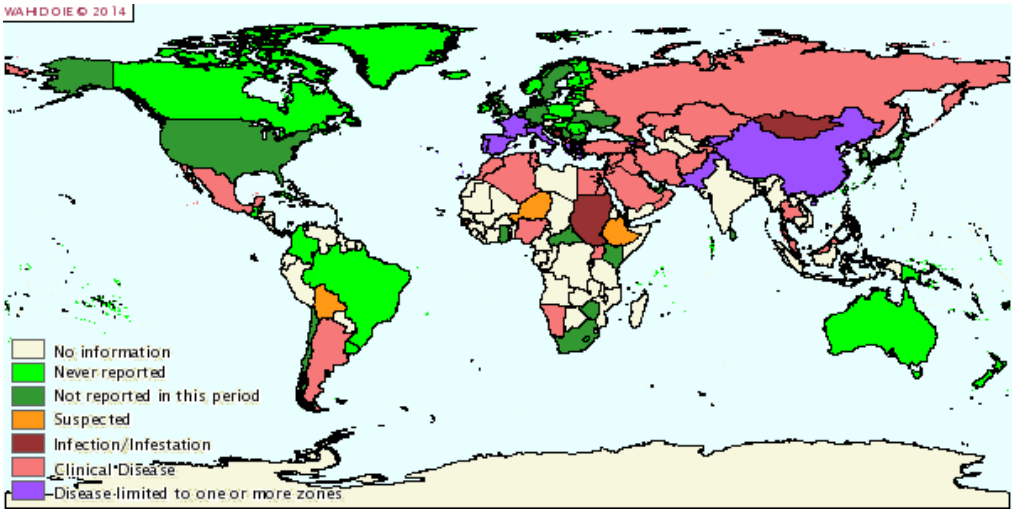


Figure 78 Disease distribution map: *B. melitensis*, Jan-Jun 2013 (WAHID, 2014)

McDermott and Arimi, 2002 highlight bovine, caprine and porcine brucellosis as important diseases of SSA but that recent studies are scant; surveillance is poor and not representative of actual disease (Figure 79 and Figure 80). Brucellosis in cattle is reported to be widespread and prevalent in SSA (Figure 79), but the prevalence is thought to vary according to the type of livestock production system (McDermott and Arimi, 2002). They describe that the incidence of brucellosis is highest in pastoralist systems of semi-arid areas, ranging between 5 and 41 % (and increases as herd size and size of landholding increases) as a result of extensive movement of cattle (and small ruminants), and coming into contact with other herds at common grazing and watering points. Prevalence in crop livestock systems in semi-humid or

highland regions is reported to be lower than in pastoralist systems of semi-arid areas and is very variable (ranging between 0 % and 25 %) (McDermott and Arimi, 2002). The prevalence reported in intensively managed herds in SSA tends to be consistent with patterns in other parts of the world, where it is found to be high in the absence of control measures (McDermott and Arimi, 2002).

The aetiologic agent for bovine brucellosis is described as *B. abortus* primarily, although *B. melitensis* has been reported and *B. suis* infections suspected. Generally, much lower prevalences of ovine and caprine brucellosis have been documented for SSA, and less surveillance data exists (Figure 80). *B. melitensis* is the main causal organism although a number of *B. abortus* infections in goats and sheep have been reported. *B. suis* infections are only rarely reported in this region.

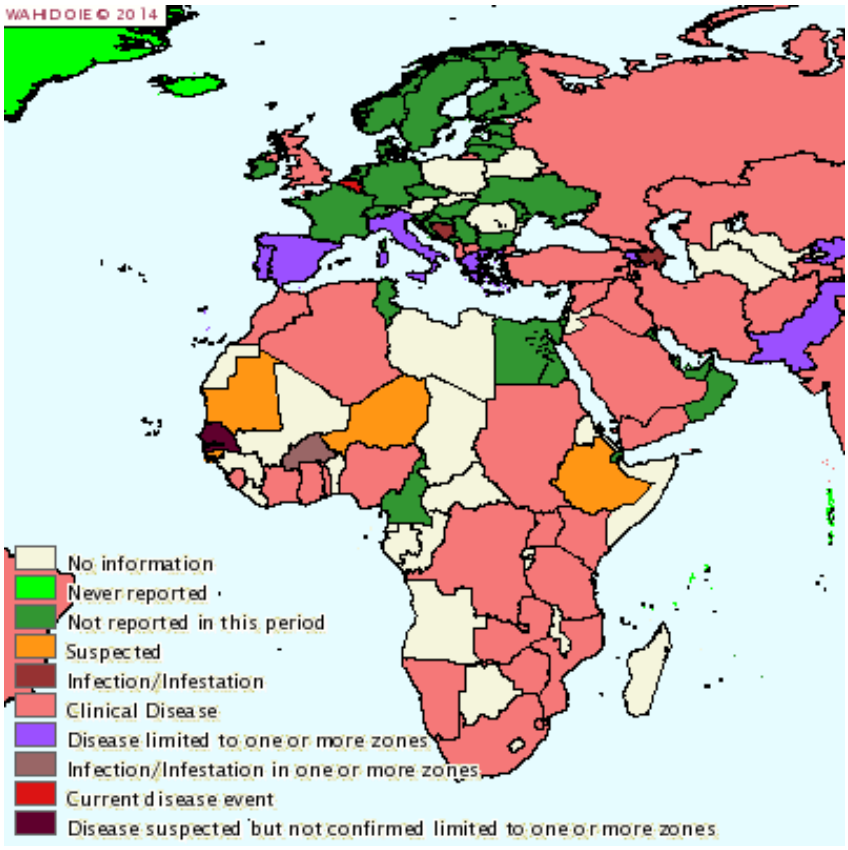


Figure 79 *B. abortus* distribution map with focus on Africa, Jan-Jun 2013 (WAHID, 2014)

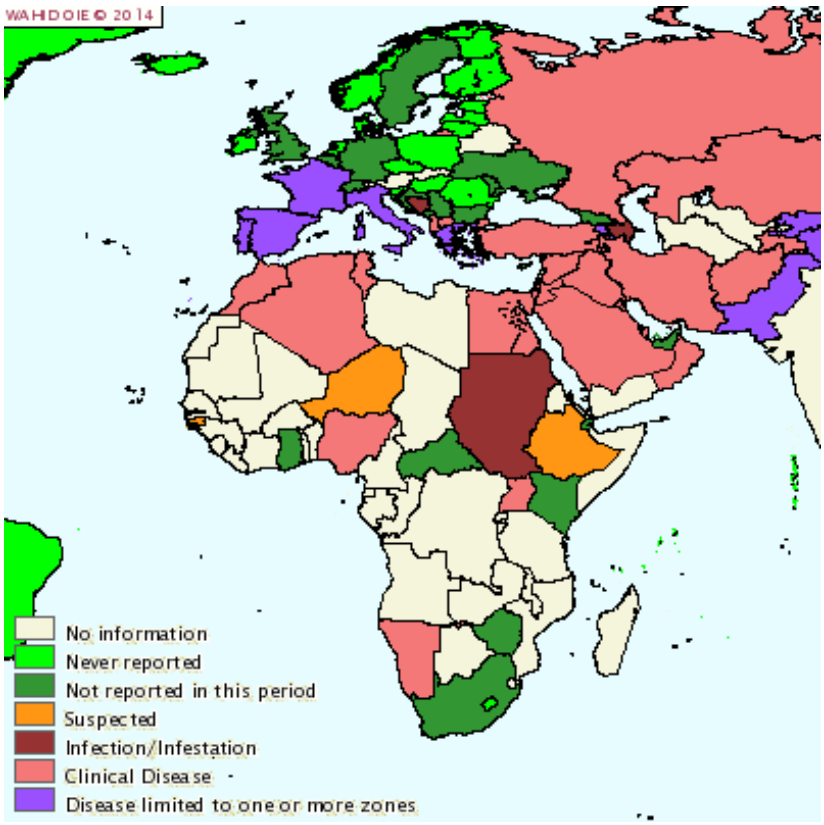


Figure 80 *B. melitensis* distribution map with focus on Africa, Jan-Jun 2013 (WAHID, 2014)

6.1.5.2 Epidemiology of human brucellosis

The incidence of human brucellosis worldwide is largely unknown. Industrial countries with active surveillance systems have a good idea of national disease status but the low incidence reported in resource poor countries reflects low levels of surveillance and reporting rather than low occurrence of disease (Dean et al., 2012). Socioeconomic, sanitary and political factors have altered the global situation. Control has been undertaken in several endemic regions (e.g. Israel and large parts of South America), new foci of infection have emerged in central Asia and the disease burden has increased in the Near East (Corbel et al., 2006, Pappas et al., 2006).

The prevalence of human brucellosis in Africa is largely unknown. North Africa is considered to endemic for brucellosis but data are scarce, and the true prevalence is grossly underestimated. Less is known about disease prevalence in SSA, but it is assumed that the disease exists throughout SSA (Pappas et al., 2006). Most human

brucellosis in SSA is derived from small seroepidemiological studies of patients with fever or high-risk populations (McDermott and Arimi, 2002, Pappas et al., 2006).

Most human cases reported are caused by *B. melitensis* but *B. abortus* and *B. suis* biovars 1, 3 and 4 are also highly infectious. Evidence suggests that *B. suis* biovar 2, although commonly infecting swine in Europe, displays little virulence for humans. *B. ovis* is not infectious for humans and human cases by *B. canis* are rare. There have been cases of human infections by brucellae from marine mammals but there is a paucity of data on other species or biovars.

6.2 Review of brucellosis in Nigeria

The following is an appraisal of the epidemiology of brucellosis in Nigeria.

6.2.1 Methods

A database search (PubMed, GoogleScholar, Cabdirect and African Journals Online) was undertaken using broad terms (Brucel* or zoonos* plus Nigeria or Africa) and screened for brucellosis and Nigeria. References in identified articles were screened and yielded 164 publications of which 37 were unobtainable. Of the remaining 127 publications, 16 were excluded as duplicates or not supported by diagnostic tests. Broad inclusion criterion were applied because (i) only one study (limited to seroprevalence in cattle) met strict scientific criteria and (ii) a critical appraisal of the grey literature allowed identification of presence of the disease, limitations of diagnostic tests, epidemiological aspects and gaps from which lessons can be drawn.

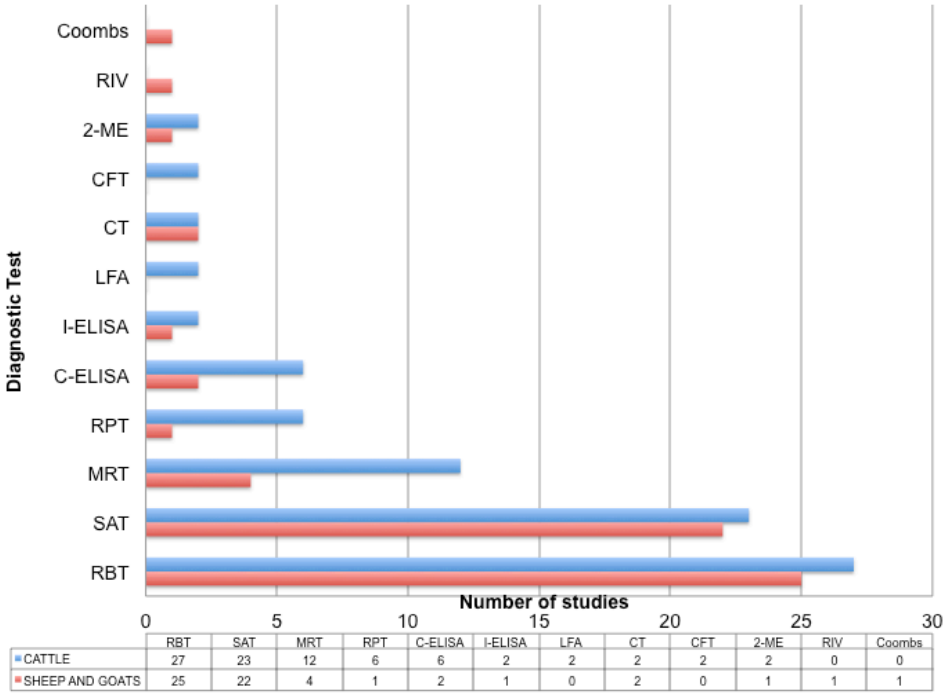
The studies were largely heterogeneous. To summarise the content data were first grouped by host (cattle, sheep, goats, camels, pigs, horses and donkeys, chickens, dogs and humans). Data extracted for cattle, small ruminants and humans are summarised in Table 57, Table 58, Table 59, Table 60. Data for other species are discussed in the text (see 6.2.2.4‘Brucellosis in other animals’ below). When several hosts were included in the same study, each was listed in the corresponding Table (the common source can be identified in the references cited in the Tables). For cattle and small ruminants, studies were further separated out into farm studies, abattoir/meat market studies and milk market studies. The farm studies were then further subdivided according to livestock production system (intensive, extensive or

not specified). Where multiple surveys (e.g. abattoir and farm) were reported in a single study, each survey was listed separately. Data were extracted for: population origin; sampling method (probability or non-probability sampling); sampling approach (investigation, random sampling, multistage sampling, systematic sampling, purposive selection, convenience sampling etc.); diagnostic test used and cut-off (see below); bias and/or gaps in sampling method description; location of study; period of sampling; sample size (total number of animals/humans sampled and total number of herds/flocks if information available) and seroprevalence (individual and herd/flock if available).

The intensive farm population (Rows A and C in Tables 57, 58, 59 and 60) corresponds to commercial, government or research institutes, and the extensive farm population (Rows B and D in Tables 57, 58, 59 and 60) to Fulani or Indigene (one study) herds/flocks exclusively. Based on personal field experience in Nigeria, differences in livestock management (e.g. nomadic and semi-nomadic Fulani) across herds of the same category were considered of limited significance and values were merged. Studies where the population was not specified were categorised as such (Row E in Tables 57, 58, 59 and 60). Some studies conducted surveys in extensively and intensively reared livestock in parallel and data has been considered separately under Row C and D in Tables 57, 58, 59 and 60. Data from abattoir/meat market studies are summarised in Row F of Tables 57, 58, 59 and 60) and milk market studies in Row G of Table 57.

Most studies screened sera (blood or milk) with more than one serological assay and therefore report a seroprevalence value based on the results of each individual test. The number of cattle and small ruminant studies which have used classical tests such as the rose Bengal test (RBT), card test (CT), serum agglutination test (SAT), rapid plate test (RPT), 2-mercaptoethanol test (2-ME), rivanol test (RIV), coombs test, complement fixation test (CFT), milk ring test (MRT) and more recent diagnostic assays such as the competitive ELISA (C-ELISA), indirect ELISA (I-ELISA), and lateral flow assay (LFA) are summarised in Figure 81. To summarise and compare data one test seroprevalence value was selected per study in this preferential order: RBT (or the equivalent Card Test), CFT, RPT, and SAT (all in blood serum). In

studies where only milk was screened with MRT, these values are reported. The rationale for this preferential selection of tests is the superior sensitivity/specificity (in the absence of brucellosis vaccination) of the prioritized tests (Greiner et al., 2009). Four authors did not report individual test results: Esuruoso (1974a) who considered samples positive when they were positive for SAT confirmed by CFT for suspicious samples; Alausa (1979c) who considered samples positive when positive for the card test or MRT or both; Pullan (1980), who used MRT screening at herd level and then RBT on individual animals of MRT positive herds; and Mai et al. (2012) who confirmed RBT positive or inconclusive samples with C-ELISA. In these cases, we used the positive/negative data provided.



	RBT	SAT	MRT	RPT	C-ELISA	I-ELISA	LFA	CT	CFT	2-ME	RIV	Coombs
CATTLE	27	23	12	6	6	2	2	2	2	2	0	0
SHEEP AND GOATS	25	22	4	1	2	1	0	2	0	1	1	1

Figure 81 Number of cattle and small ruminant studies that have used specific tests for serological screening

The data table corresponds to total number of studies that have employed each test for each species. The overall number of studies is greater than the total number of papers retrieved because most papers screened sera with more than one serological assay. Tests include Rose Bengal test (RBT), card test (CT), serum agglutination test (SAT), rapid plate test (RPT), 2-mercaptoethanol test (2-ME), rivanol test (RIV), Coombs test, complement fixation test (CFT), milk ring test (MRT) and more recent diagnostic assays such as the competitive ELISA (C-ELISA), indirect ELISA (I-ELISA), and lateral flow assay (LFA).

The presentation of average prevalence values calculated from studies using different tests, in different populations and using different sampling designs is not valid and so only prevalence ranges are presented.

Values were not averaged across analogous livestock production systems using weighting approaches taking into account test performance or sample size because i) the lack of standardization of tests (origin of antigens, positive and negative controls, cut-off criteria), ii) the application of brucellosis vaccination in some of the herds tested in earlier studies and iii) non-probability sampling across studies, would have lead to misleading estimates of average prevalence. This limits interpretation of the range of prevalence values presented in Table 58 and Table 59. To overcome limitations, RBT values only are considered in Table 60 and Table 61, which yield narrower ranges as they are based on fewer studies and a simpler, more robust test. The overall pattern when comparing intensive and extensive populations is the same.

6.2.2 Results

6.2.2.1 Period of sampling and spatial distribution

Historically, two peaks of brucellosis reporting are evident (Figure 82): the first coincided with establishment of intensive government farms in the 1970s to promote meat production and reduce imports (Box 1); the second with the post-millennium development goals public health agenda, increased interest in neglected zoonotic diseases and private sector growth. Significantly, the trough coincides with the oil boom of the 1970's (Box 1). Figure 82 shows studies by animal species and Figure 83 the spatial distribution of animal and human studies.

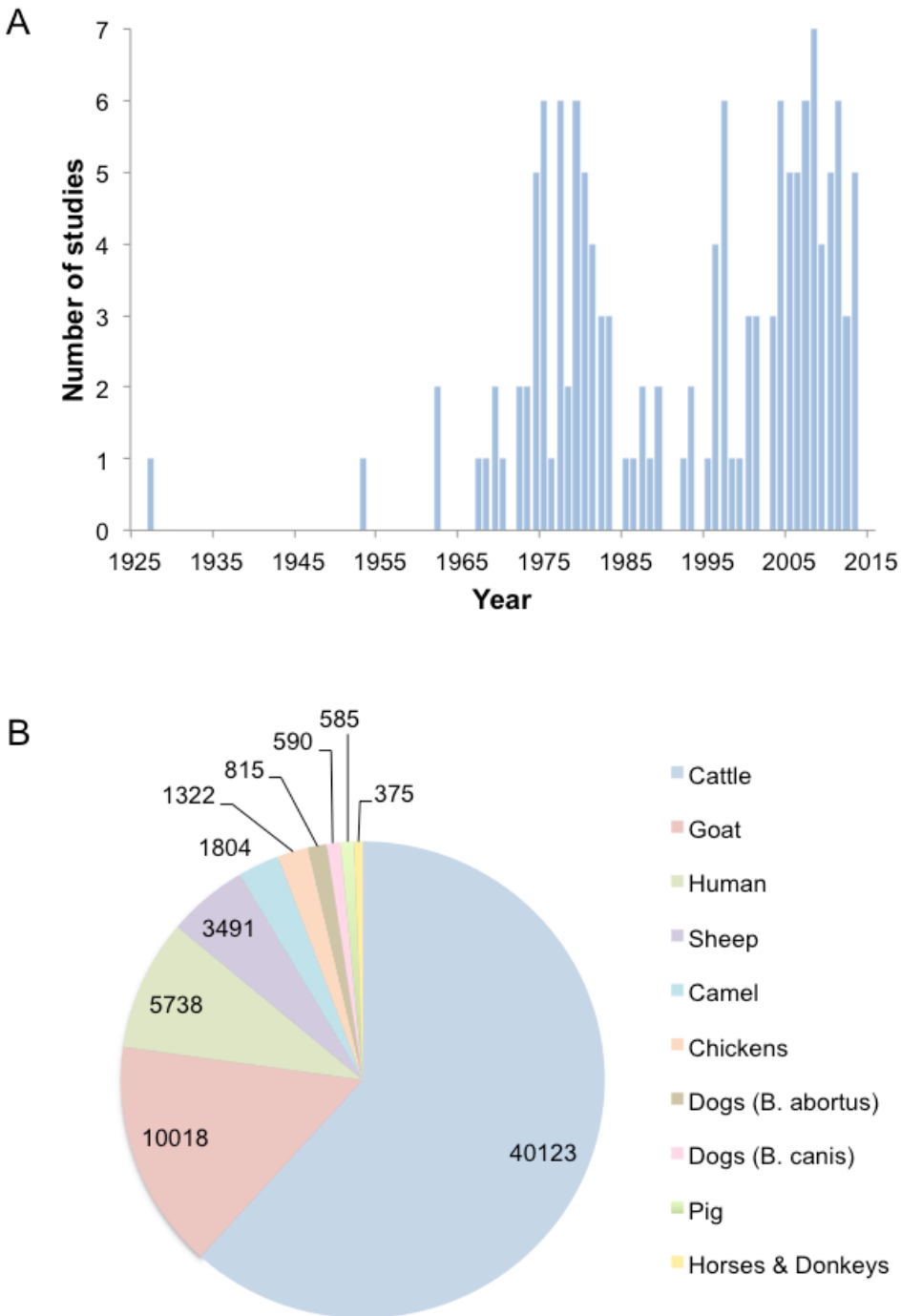


Figure 82 Distribution of studies on brucellosis in Nigeria according to (A), year of publication, and (B), host investigated (numbers correspond to cumulative sample size across all studies for each host species).

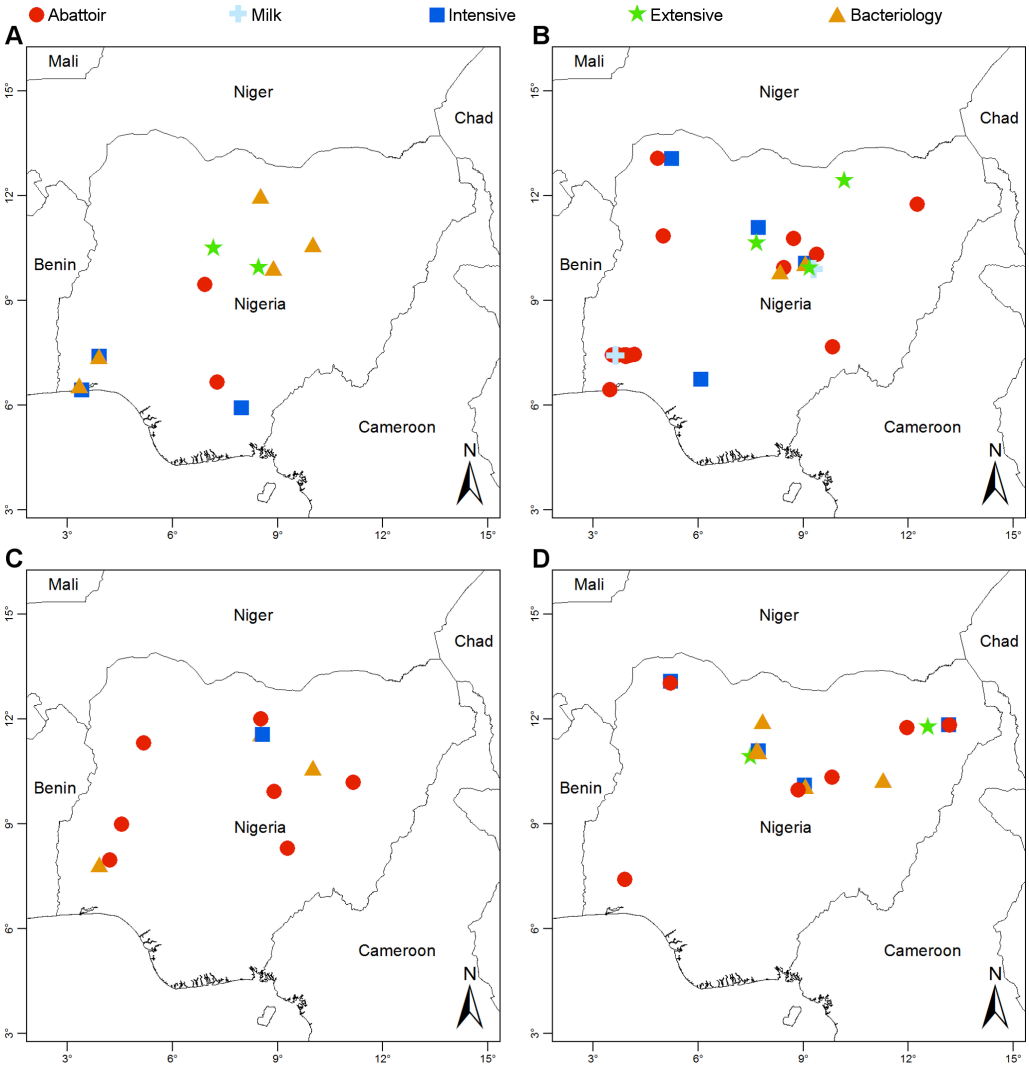


Figure 83 Location of brucellosis studies in Nigeria. (A), cattle; (B), sheep and goats; (C), camels and pigs; and (D), humans.

6.2.2.2 Cattle brucellosis

Since brucellosis was first reported in Nigeria in 1927 (Banerjee and Bhatty, 1970) only five studies have provided bacteriological data for cattle (Figure 83). In the West, studies in range cattle and in a University herd described the isolation of *Brucella* strains, probably *B. abortus* (Esuruoso, 1974b). This species was properly identified in studies in Government and private farms and in settled Fulani herds in the Centre and North (Bale and Kumi-Diaka, 1981, Eze, 1978 , Ocholi et al., 2004b). In total, 58 isolates were classified as *B. abortus* biovar 1 (54 strains), biovar 2 (1

strain), biovar 3 (2 strains) and biovar 4 (1 strain). *B. melitensis* has not been reported in cattle, although there is close contact with small ruminants.

The bulk of the evidence is derived from serological studies (Figure 82) but limitations in the application of serological tests make data difficult to interpret. Early studies used RPT or SAT, two tests lacking sensitivity and specificity (Greiner et al., 2009, Davies, 1971, Blasco et al., 1994a). The RBT (or the equivalent Card Test) was applied shortly after its development and has been widely used Table 57 and Table 59 and Figure 81). Despite the excellent specificity and sensitivity of RBT (Greiner et al., 2009, Davies, 1971, Blasco et al., 1994a), the literature reviewed reflects the misconception that RBT is a test of low specificity which, in the absence of brucellosis vaccination or the false positive serological reaction phenomenon caused by cross-reacting bacteria, needs to be confirmed (aspects of diagnostic tests are discussed in more detail in Chapter 7). However, meta-analysis performed using strict criteria (Greiner et al., 2009) shows that RBT specificity is in fact better than that of iELISA and cELISA, two tests used in some works to "confirm" the RBT results. Indeed, the OIE Manual (http://www.oie.int/en/international-stan dard-setting/terrestrial-manual/access-o nline/; Chapter 2.4.3. Bovine Brucellosis) clearly states that these other tests can also sometimes give a positive result because of S19 vaccination or of false-positive serological reactions.

While RBT is a good choice, inadequate standardization results in considerable sensitivity (but not specificity) variation (Blasco et al., 1994a). RBT standardization and origin was inadequately described in 15 out of 46 papers and 6 investigations used locally prepared antigens. Competitive or indirect ELISA kits were used according to manufacturer instructions but were never validated under local conditions (cut-offs established in brucellosis-free and good hygienic conditions cannot be extrapolated to endemic areas) (Greiner and Gardner, 2000).

Across Nigeria 14000, 11000 and 8000 cattle have been sampled in different studies from abattoirs (animals from both extensive and intensive systems), extensive and intensive herds respectively, but the data (Table 57 and Table 59, Figure 82 and Figure 83) illustrate the limitations in time and space of the studies. A total of 1800 cattle correspond to the North, half this number (1000) to the West and only small

numbers to the East and South. Abattoir studies cannot provide spatial information due to country wide animal movements. Only five out of the 46 prevalence studies applied probability based sampling methods (Junaidu et al., 2011, Cadmus et al., 2013, Farouk et al., 2013, Maurice et al., 2013, Mai et al., 2012), and only one describes the method in sufficient detail (Mai et al., 2012), but even this study is bias because herds were selected based on proximity to a reliable laboratory and farmer cooperation. Studies of intensive farms have focused mainly on infertility or abortion outbreaks and few cattle were sampled (Table 57). Most intensive system studies were undertaken in the West before 1986 (Figure 82), a period of intense interest in the livestock sector (Box 1 and Table 57, Row A). Since 1986 more investigations have been reported in extensive cattle systems Table 57, Row B) and from abattoirs Table 57, Row F). Clearly there are few good quality data on brucellosis in Nigeria and discussion must bear in mind these limitations.

6.2.2.2.1 Extent to which the extensive and intensive cattle management systems are affected by brucellosis.

In Nigeria, most cattle are reared extensively in the North, belonging to nomadic, semi-nomadic or transhumant Fulani pastoralists. Early official veterinary records do not regard brucellosis as a hazard in these herds (Banerjee and Bhatty, 1970, Anonymous, 1958) and most studies conducted independently in the extensive and intensive systems suggest a lower prevalence in the former (Table 57 and Table 59, Rows A and B) (Esuruoso, 1974a, Eze, 1978). This observation is consistent with the low transmission deemed typical of pastoralist systems (Racloz et al., 2013).

The inverse profile can be observed for studies that have looked at intensive and extensive system populations in parallel (Table 57 and Table 59, Rows C and D). A recent probability sampling study (Mai et al., 2012) (performed in Adamawa, Kaduna and Kano, northern Nigeria), reports RBT seroprevalences of 45.1% (nomadic), 22.0% (semi-nomadic), 23.8% (commercial) and 15.9% (zero-grazing). Using a competitive ELISA kit as the reference, the authors assumed that 42.8 to 24.7% of these RBT results were false positives, but higher prevalence in the extensive than intensive system was also observed with the ELISA. Another recent but more limited work reported higher (but not statistically significant) numbers of

RBT positives in extensively than in intensively managed herds (11.6% versus 3.1%, respectively) in Plateau State (North Central Nigeria) (Maurice et al., 2013). These results suggest brucellosis prevalence has been increasing in extensive systems over time (Mai et al., 2012). These aspects of brucellosis epidemiology are not trivial and further studies are necessary to confirm whether there is an increase of brucellosis in extensively managed herds and its distribution across the country. Unfortunately, the gap in information between the early 1980's and late 1990's precludes any possibility of doing this with the data available (Figure 82).

6.2.2.2.2 Extensive nomadic herds as reservoirs of disease

Brucellosis transmission is generally lower in pastoralist systems because of low reproductive rates, animal movements and environmental circumstances (Racloz et al., 2013). However, brucellosis transmission could increase as a result of the settling of migratory herds and emerge from increased contacts between these herds and unprotected intensive commercial or settled semi-intensive herds. This possibility has seldom been investigated in Sub-Saharan Africa. One article provides evidence of this kind of transmission and of its dramatic impact on susceptible populations in the 1970's (Alausa, 1979c).

In a large brucellosis outbreak in Ibapara, out of 10 government, three private settled and 12 Fulani herds tested, 11 herds were found to be positive using a combination of the MRT and Card Test. All 11 positive herds belonged to Fulani pastoralists, '*nomadic herdsmen that move only within the district, and within few kilometres from previous settlements'*. The outbreak coincided with the Sahelian drought that saw a general reduction in the cattle population of Nigeria and prompted an influx and settling of nomadic herds in Ibapara. The outcome was a widespread epidemic of bovine brucellosis with a severe increase in human cases. Fulani herdsmen complained of being unwell and unable to look after their cattle, and 51.5% herdsmen, 23.5% abattoir workers and 3.1% of high school students were serologically positive with the Card Test. Calf losses were reported resulting in a shortage of meat and protein under-nutrition in the local populace.

6.2.2.3 Brucellosis in small ruminants

Small ruminants represent a major source of meat in Nigeria and are often reared alongside cattle. Their distribution is not known with certainty; Falade et al. (1974) cite early sources according to which 70% of goats were in the North, 20% in the East and 10% in the West, and about 60% of rural households in the northern, 50% in the eastern and 40% in the western states kept goats. 15% of sheep and goats were reared under nomadic conditions at the end of the 20th Century (Brisibe et al., 1996).

Bacteriological evidence for *Brucella* in small ruminants is scarce (Figure 83). An early study claimed the isolation of *B. abortus* in sheep and goats but the methodology used in species identification is unclear (Okoh, 1980). *B. melitensis* biovar 1 (22 strains) and *B. abortus* biovar 1 (8 strains) were isolated from goats in western Nigeria (Falade, 1981a). However, the reported biochemical characteristics of the *B. melitensis* strains are atypical. *B. melitensis* was recently described in sheep and goats in northern Nigeria but the 10 strains were not definitively typed (Bale et al., 2003a). A study in Bauchi (central Nigeria) clearly demonstrated *B. abortus* but not *B. melitensis* in sheep (Ocholi et al., 2004b). Interestingly, 7 *B. abortus* strains were isolated from sheep reared in contact with infected cattle (Ocholi et al., 2005). Although *B. abortus* preferentially infects cattle, it can persist in sheep (Luchsinger and Anderson, 1979) and the significance of *B. abortus* infection in small ruminants in the mixed breeding systems of Sub-Saharan Africa requires further investigation.

There are fewer and more limited serological studies in small ruminants than in cattle (Figure 82, Table 58 and Table 60). Significant misuse of tests were: application of MRT (not useful in small ruminants [Alton et al., 1988]) in four studies; interpretation that animals were infected by *B. melitensis* based on a comparison of titres to *B. abortus* and *B. melitensis* antigens (Junaidu et al., 2010, Okewole et al., 1988, Onunkwo et al., 2009), a discrimination that is not possible by serology and indicates inadequate antigen standardization.

Studies in intensive or semi-intensive systems are not only scarce but also biased because most investigations focused on cattle abortions with simultaneous sampling of small ruminants (compare references in Table 57 and Table 58). In fact, contagion from cattle was often considered the origin of infection. Only one study was

performed on intensively or semi-intensively raised small ruminants in the West (Falade et al., 1974), the others for this region consisting of abattoir surveys (Table 58 and Table 60). Studies in extensive systems were all undertaken in the North (Rows B and D Table 58 and Table 60) and the epidemiology in sedentary and nomadic flocks in other regions is unknown. Values suggest brucellosis prevalence is higher in intensive than extensive systems for small ruminants (Table 58 and Table 60, Rows A, B, C and D) these trends have to be interpreted with caution.

According to two studies performed in the 1960's, small ruminant brucellosis was not a problem on government farms, but most surveys were undertaken in the cattle-dominated North hence no information was available for other regions (Figure 83) (Adams and McKay, 1966, Kramer et al., 1967). Fifteen years later, one study in northern Nigeria later found significant rates of infection (13.8 and 15.1% averages for sheep and goats, respectively) (Bale et al., 1982). This same study reported rates of infection in institutional (i.e. intensive) flocks about four times higher than in local (extensive) flocks for both sheep and goats (Table 58), and attributed the difference to an increased transmission caused by intensification (Bale et al., 1982). A recent study (Bertu et al., 2010) found overall prevalence values of 9.3% for sheep and 10.1% for goats, which are comparable to the values found 30 years previously (Bale et al., 1982), but husbandry-specific values were not obtained.

Ten studies have investigated sheep and goats for brucellosis in trade settings (Table 58, Row F) and, while values do not reflect the situation at farm level, they confirm the presence of brucellosis in small ruminants in the North. Two abattoirs studies in the West found low prevalence values (0.3-0.9% and 0% for goat and sheep respectively) (Falade, 1980, Cadmus et al., 2006) but since animals come mostly from other parts of Nigeria the situation in the West remains unknown.

6.2.2.4 Brucellosis in other animals

In Nigeria *B. abortus* has been isolated from horses (Ocholi et al., 2004a, Ocholi et al., 2004b) and antibodies have been reported in donkeys (Sadiq et al., 2012) dogs (Adesiyun et al., 1986, Osinubi et al., 2005, Cadmus et al., 2011) and fowl (Bale and Nuru, 1982, Junaidu et al., 2006, Gugong et al., 2012, Cadmus et al., 2011) (Figure 82). The role of these non-ruminant species in disease transmission is not proven

(Rementsova, 1985), since they are unable to act as reservoirs, once brucellosis is eradicated in domestic ruminants, they are considered spill-over hosts or sentinels.

Camels are distributed along the Northern borders of Nigeria and nomadism is common, often across borders. At the turn of the 20th Century, estimated numbers of camels in Nigeria varied from 90,000 (Adamu and Ajogi, 1999) to 25,000, substantially greater than an estimate of 18,000 in 1978 (Kudi et al., 1997). Both *B. abortus* and *B. melitensis* can infect camels but *Brucella* has never been isolated from these animals in Nigeria (Adamu et al., 2007, Egbe-Nwiyi et al., 1999, Zaria et al., 1990). Serological studies are particularly difficult to interpret because brucellosis tests have not been properly evaluated in these animals (Sprague et al., 2012). Abattoir studies in northern Nigeria reported 1.3-14.8% seropositivity using SAT (Adamu and Ajogi, 1999, Kudi et al., 1997, Okoh, 1979, Sadiq et al., 2010) in camels from Nigeria and Chad, Niger and Cameroon (Figure 83). In Borno State, two MRT and RBT studies of range camels reported positive animals (Adamu et al., 2007, Sadiq et al., 2010). However, the MRT has been proven useful only in cattle (Alton et al., 1988) and the RBT is dependent on the effect of acidic pH on ruminant IgG and IgM (Diaz et al., 2011, Levieux, 1974). Since camelids and ruminants differ markedly in immunoglobulin repertoire and structure (Hamers-Casterman et al., 1993), RBT results should be interpreted with caution. Camels are herded with sheep and goats and, to a lesser extent, cattle (Kudi et al., 1997) and their role in the epidemiology of brucellosis in Nigeria is unclear.

Pigs represent approximately 4.5% of the meat market in Nigeria (Nwanta et al., 2011). An early study claimed isolation of *B. suis* from animals positive in SAT (Bale and Nuru, 1985) but a small-scale bacteriological study failed to isolate *Brucella* (Ocholi et al., 2004b). An investigation in government farms during a cattle abortion outbreak (Kramer et al., 1967), a study in intensive and semi-intensive farms in the South (Nwanta et al., 2011) and an abattoir study in the West (Cadmus et al., 2006) found no or very few RBT positive animals. In contrast, a recent abattoir study in Central Nigeria reported 30% of 281 pigs RBT positive (Ngbede et al., 2013) (Figure 83). In the absence of bacteriological evidence or protein-based tests,

these data have to be interpreted with caution because pigs are prone to false positive serological reactions with RBT, CFT and ELISA (Dieste-Perez et al., 2014).

6.2.2.5 Human brucellosis

The first cases of human brucellosis confirmed by laboratory tests were reported in Nigeria in 1941 (Elmes, 1941) and 1962 (Collard, 1962a), and even during this period under-detection was suspected (Collard, 1962b). A decade later, few laboratories could perform these tests and this, combined with low suspicion, was again thought to lead to under-detection (Alausa and Osoba, 1975). This review shows that these circumstances have not changed.

Human seroprevalence data are summarized in Table 61 and Figure 83 shows the geographical location of studies. Although they strongly suggest the importance of the human disease, exact figures cannot be derived from most surveys. The studies based solely on RBT confirm exposure to *Brucella* of butchers, abattoir workers and herdsmen. However, they do not necessarily represent the proportion of true disease because a positive RBT result can be caused by contact or infection and needs to be interpreted according to the clinical picture (Diaz et al., 2011). Several studies complemented RBT with SAT and 2-mercaptoethanol tests, both of which detect only agglutinating antibodies; since these antibodies disappear in long-standing cases, the data only reflect recent infections. Moreover, SAT diagnostic titre varies from 50 to 200 international units (the diagnostic titre most often used in Nigeria was of 100 international units) depending on the origin (urban/rural and endemic/non-endemic areas) and exposure of the patient (Diaz et al., 2011). Complementary tests that detect non-agglutinating antibodies (competitive ELISA, Coombs and CFT) were implemented in only two studies, one using competitive ELISA whose diagnostic cut-off for human brucellosis is unknown (Diaz et al., 2011).

There are no reports of *Brucella* isolation from human cases and it is not known to what extent human brucellosis in Nigeria is caused by *B. abortus* or *B. melitensis*. Interpretation of human infection caused by *B. melitensis* or *B. abortus* on the basis of different titres with *B. melitensis* and *B. abortus* antigens is deceptive (Ofukwu et al., 2007). Misdiagnosis may be frequent; one abattoir study found RBT positive

individuals complained of frequent treatments for malaria without improvement while others complained of joint pain and general weakness (Cadmus et al., 2006).

6.2.3 Gaps and Questions

This review has identified major gaps in epidemiological data, diagnostics and control, and misconceptions surrounding brucellosis diagnosis. After 100 years we know surprisingly little on the disease agent in Nigeria, and good quality information - essential for evaluation of zoonotic potential and for establishment of control measures - is still lacking. The main questions are:

1. What *Brucella* species and strains are circulating in animal and human populations of Nigeria?
2. Are *B. melitensis* and/or *B. suis* present in Nigeria, and if so, where?
3. What is the dominant *B. abortus* biovar in cattle and how does it differ in terms of virulence and biological properties from European strains?
4. What is the prevalence of brucellosis in the different livestock production systems (extensive and intensive)?
5. Are rural-urban migration, changing trends in livestock management and increased intensification creating the conditions for emergence of disease?
6. How are serological tests performing in the Nigerian context?

Row label	Population / *Production system*	Tests, no. studies, no. individuals and no. herds on which **INDIVIDUAL PREVALENCE** is based					Range of ind prev (%)	Tests, no. studies and no. herds on which **HERD PREVALENCE** is based			Range of herd prev (%)	Refs.[11]
		Tests (no. studies)[1]	**No. studies[2]**	**No. individuals[3]**	**No. studies[4]**	**No. herds[5]**		**Tests (no. studies)[6]**	**No. studies[7]**	**No. herds[8]**		
	Farm											
A	***Intensive***	SAT (6), RBT (4), RPT (2), MRT (1)	13	4341	12	>47	0-47	SAT (5), RBT (4), MRT (1)	10	37	0-100	Refer to Table S1
B	***Extensive***	RBT (2), MRT (2), MRT/RBT (1)	5	4974	4	>171	2-15	MRT/RBT(1)	1	8	13	Refer to Table S2
	Int/Ext [9]											
C	Intensive	RBT (2), RPT (2), SAT/CFT (1), RBT/ELISA (1)	6	3784	2	>20	3-33	SAT/CFT (1)	1	9	100	Refer to Table S3
D	Extensive	RBT (2), RPT (2), SAT/CFT (1), RBT/ELISA (1)	6	6783	2	>259	0-45 *(41)*[10]	SAT/CFT (1)	1	4	0-100	
E	***Not specified***	RBT (3), CT/MRT (1)	4	5576	3.5	>199	0-50	RBT (2), CT/MRT (1)	3	134	0-44	Refer to Table S4
F	**Abattoir**	RBT (15), RPT (1), SAT (1)	17	14265	NA	NA	0-22	NA	NA	NA	NA	Refer to Table S5
G	**Milk Market**	MRT (2)	2	410	NA	NA	7-12	NA	NA	NA	NA	Refer to Table S6

[1] Range of diagnostic tests and respective number of studies for each test on which individual prevalence values in table have been based (see text).
[2] Number studies on which total number of individuals sampled and individual prevalence values have been based.
[3] Sum of animal sample size for each study for which individual prevalence data is available.
[4] Number of studies, out of total number of studies on which individual prevalence is based, which report number of herds sampled.
[5] Minimum estimate of number of herds sampled for each production system category. Not all studies reported number of herds sampled hence true value must be superior (>) to that in table.
[6] Range of diagnostic tests and respective number of studies on which herd prevalence values in table have been based (see text).
[7] Number of studies on which total number of herds sampled and herd prevalence values have been based.
[8] Sum of number of herds sampled for each study for which herd prevalence data is available.
[9] Studies sampling extensive and intensive flocks in parallel.
[10] Value of 41% prevalence corresponds prevalence non-adjusted for sensitivity and specificity (apparent prevalence = [true prevalence (0.879+0.998-1)] +1 – 0.998]; 0.998= specificity of RBT*ELISA in test series; 0.879=sensitivity of test series, see Mai et al. 2012).
[11] Refer to Ducrotoy et al. (2014) and supplementary tables in appendix for references.

Table 57 Summary of brucellosis serology studies in cattle in Nigeria

Row label	Population *Production system*	Tests, no. studies and no. individuals on which **INDIVIDUAL PREVALENCE** is based						Range of ind prev (%)		Tests, no. studies and no. flocks on which **FLOCK PREVALENCE** is based						Range of flock prev (%)		Refs.[9]
		Test (no. studies)[1]		No. studies[2]		No. Individuals[3]				Test (no. studies)[4]		No. studies[3]		No. flocks[4]				
Species		S	G	S	G	S	G	S	G	S	G	S	G	S	G	S	G	
	Farm																	
A	***Intensive***	RBT (4), RPT (1), SAT (1)	RBT (2), RPT (1)	6	3	594	234	0-76	0-33	RBT (4), SAT (1)	RBT (2)	5	2	5	2	100	100	Refer to Table S9
B	***Extensive Int/Ext***[7]	RBT (1)	RBT (2)	1	2	210	643	5	6-29	NA[8]	NA	0	0	NA	NA	NA[4]	NA	Refer to Table S10
C	Intensive	RBT (2), SAT (1)	RBT (2)	3	2	734	1053	0-21	5-21	NA	NA	0	0	NA	NA	NA	NA	Refer to Table S11
D	Extensive	RBT (2), SAT (1)	RBT (2)	3	2	570	557	2-13	6-16	NA	NA	0	0	NA	NA	NA	NA	
E	***Not specified***	RBT (1)	SAT (2), RBT (1)	1	3	50	985	2	0-5	NA	NA	0	0	NA	NA	NA	NA	Refer to Table S12
F	**Abattoir**	RBT (6), SAT (1)	RBT (8), SAT (2)	7	10	1376	6656	0-15	0-17	NA	NA	NA	NA	NA	NA	NA	NA	Refer to Table S13

[1] Range of diagnostic tests and respective number of studies for each test on which individual prevalence values in table have been based (see text).
[2] Number studies on which total number of individuals sampled and individual prevalence values have been based.
[3] Sum of animal sample size for each study for which individual prevalence data is available.
[4] Range of diagnostic tests and respective number of studies on which flock prevalence values in table have been based (see text).
[5] Number of studies on which total number of flocks sampled and herd prevalence values have been based.
[6] Sum of number of herds sampled for each study for which flock prevalence data is available.
[7] Studies sampling extensive and intensive flocks in parallel.
[8] Not applicable.
[9] Refer to Ducrotoy et al. (2014) and supplementary tables in appendix for references.

Table 58 Summary of brucellosis serology studies in sheep (S) and goats (G) in Nigeria

Row label	Population / *Production system*	No. studies, no. individuals and no. herds on which **INDIVIDUAL PREVALENCE** is based				Range of ind prev (%)	No. studies and no. herds on which **HERD PREVALENCE** is based		Range of herd prev (%)	Refs.[9]
		No. studies[1]	No. individuals[2]	No. studies[3]	No. herds[4]		No. studies[5]	No. herds[6]		
	Farm									
A	***Intensive***	4	333	4	12	0-33	4	12	0-100	Refer to Table S1
B	***Extensive***	2	3561	2	133	2-16	0	NA[8]	NA	Refer to Table S2
	Int/Ext [7]									
C	Intensive	2	152	0	NA	3-8	0	NA	NA	Refer to Table S3
D	Extensive	2	270	0	NA	5-12	0	NA	NA	
E	***Not specified***	3	3926	2.5	>174	0-50	2.5	109	0-22	Refer to Table S4
F	**Abattoir**	15	12079	NA	NA	0-22	NA	NA	NA	Refer to Table S5

[1] Number of studies using RBT on which individual prevalence values in table have been based (see text).
[2] Sum of animal sample size for each study for which individual prevalence data is available.
[3] Number of studies, out of total number of studies, on which individual prevalence is based, which report number of herds sampled.
[4] Minimum estimate or true number of herds sampled for each production system category. Not all studies reported number of herds sampled hence true value must be superior (>) to that in table.
[5] Number of studies using RBT on which herd prevalence values in table have been based (see text).
[6] Sum of number of herds sampled for each study for which herd prevalence data is available.
[7] Studies sampling extensive and intensive flocks in parallel.
[8] Not applicable.
[9] Refer to Ducrotoy et al. (2014) and supplementary tables in appendix for references.

Table 59 Summary of brucellosis RBT studies in cattle in Nigeria.

Row label	Population *Production system*	No. studies and no. individuals on which **INDIVIDUAL PREVALENCE** is based				**Range ind prev (%)**		No. studies and no. flocks on which **FLOCK PREVALENCE** is based				**Range flock prev (%)**		**Refs.**[7]
		No. studies[1]		**No. individuals**[2]				**No. studies**[3]		**No. flocks**[4]				
Species		**S**	**G**	**S**	**G**	**S**	**G**	**S**	**G**	**S**	**G**	**S**	**G**	
	Farm													
A	***Intensive***	**4**	**2**	179	124	14-76	21-33	4	2	4	2	100	100	Refer to Table S9
B	***Extensive***	**1**	**2**	210	643	5	6-29	0	0	NA[6]	NA	NA	NA	Refer to Table S10
	Int/Ext[5]													
C	Intensive	**2**	**2**	681	1053	0-21	5-21	0	0	NA	NA	NA	NA	Refer to Table S11
D	Extensive	**2**	**2**	521	557	5-13	6-16	0	0	NA	NA	NA	NA	
E	***Not specified***	**1**	**1**	50	28	2	0	0	0	NA	NA	NA	NA	Refer to Table S12
F	**Abattoir**	**6**	**8**	846	3890	0-15	0-17	NA	NA	NA	NA	NA	NA	Refer to Table S13

[1] Number of studies using RBT on which individual prevalence values in table have been based (see text).
[2] Sum of animal sample size for each study for which individual prevalence data is available.
[3] Number of studies using RBT on which herd prevalence values in table have been based (see text).
[4] Sum of number of herds sampled for each study for which herd prevalence data is available.
[5] Studies sampling extensive and intensive flocks in parallel.
[6] Not applicable.
[7] Refer to Ducrotoy et al. (2014) and supplementary tables in appendix for references.

Table 60 Summary of brucellosis RBT studies in sheep (S) and goats (G) in Nigeria

	Region	Diagnostic test (cut-off)	Complementary tests	% Prevalence (n)	Refs.[1]
Occupationally exposed					
Abattoir workers	West	SAT (100 iu)	2-ME	39 (170)	[25]
	West	RBT		24 (51)	[23]
	North	RBT	SAT	0 (40)	[123]
	South	SAT (NS)		27 (164)	[125]
Butchers & abattoir workers	West	RBT		64 (11)	[58]
Butchers	West	SAT (100 iu)	2-ME	21 (38)	[25]
	West	SAT (100 iu)	2-ME	16 (51)	[25]
	North	RBT	SAT	5 (101)	[113]
Herdsmen	West	SAT (100 iu)	2-ME	74 (104)	[25]
	West	SAT (100 iu)	2-ME	12 (99)	[25]
	West	SAT (100 iu)	2-ME	5 (44)	[25]
	North	SAT (100 iu)		70 (71)	[126]
	West	RBT	2-ME	51 (173)	[23]
	West	SAT (100 iu)	2-ME	7 (20)	[102]
	West	RBT		0 (10)	[58]
	North	RBT	SAT, c-ELISA	7 (28)	[101]
Veterinary workers	West	SAT (100 iu)	2-ME	5 (44)	[25]
	South	SAT (NS)		16 (86)	[125]
Cattle control post workers	West	SAT (100 iu)	2-ME	21 (18)	[25]
Agricultural college students	West	SAT (100 iu)	2-ME	12 (300)	[102]
Hospital studies					
Febrile individuals					
Students	North	RBT	SAT	8 (122)	[127]
Civil servants	North	RBT	SAT	4 (100)	[127]
Traders	North	RBT	SAT	2 (53)	[127]
Housewives	North	RBT	SAT	2 (62)	[127]
Crop farmers	North	RBT	SAT	0 (6)	[127]
Health workers	North	RBT	SAT	0 (10)	[127]
Children (1-15 years)	North	RBT	SAT	10 (93)	[127]
Village farmers	North	RBT	SAT	6 (114)	[91]
Traders and breeders	North	RBT	SAT	34 (62)	[91]
Abattoir workers, butchers	North	RBT	SAT	44 (32)	[91]
Civil servants	North	RBT	SAT	4 (634)	[91]
Others	North	RBT	SAT	6 (198)	[91]
Not specified					
Patients	West	SAT (50 iu)	RBT, Coombs, CFT	6 (738)	[128]
Patients and personnel	West	SAT		9 (176)	[129]
Patients and personnel	North	RBT	SAT	0 (64)	[123]
Personnel	North	RBT	SAT	0 (90)	[123]
Blood donors, ante-natal women, male patients	West	SAT (100 iu)	2-ME	11 (1192)	[25,130]
Blood donors	West	SAT (100 iu)	2-ME	21(178)	[25]
Blood donors	South	SAT (NS)		12 (50)	[125]
Others					
High school students	West	RBT		3(65)	[23]

[1] Refer to Ducrotoy et al. (2014) in appendix for references.

Table 61 Summary of brucellosis studies in humans in Nigeria.

7 Chapter 7 Brucellosis diagnostics

7.1 Introduction

There are no pathognomonic symptoms for brucellosis and laboratory tests are therefore required to make a diagnosis of the disease. A wide range of different tests have been developed over time demonstrating that the 'perfect test' (easy to use, robust, affordable and able to identify all infected individuals) is not yet available. Choosing the right test for the right purpose is not a straightforward task. The search for the most appropriate test can be likened to walking through a 'diagnostic labyrinth', as a result of technical issues and complex biological, epidemiological and socioeconomics factors, including: 1) the silent behaviour of the pathogen towards the immune system and its intracellular niche; 2) a complex antigenic structure shared by field and vaccinal strains, some closely related α-2 *Proteobacteria* neighbours and a few gram-negative bacteria including *Yersinia enterocolitica* O:9, *Escherichia coli* 0157 and *Salmonella* group N (O:30); 3) the existence of largely different management conditions of the animal hosts, opportunities for transmission and epidemiological contexts (endemic versus *Brucella*-free); 4) the facilities available for diagnosis and 5) the purpose of screening with respects to control and eradication versus surveillance.

In this context an understanding of equivalences and differences between tests in terms of their performance and technical requirements and their suitability for use in different animal species is essential. In this chapter tests commonly used for diagnosis of brucellosis in ruminants and humans are briefly reviewed. The selection and implementation of tests for brucellosis diagnosis in the KGR is described and justified (i.e. which tests were chosen and why?). To conclude, the suitability and performance of tests selected for use the KGR is critically appraised. One of the main objectives of this chapter is to assess simple tests under field and laboratory conditions. Selection of tests for use in the field is justified and discussed.

7.2 Review of diagnostic tools

The diagnosis of brucellosis is based on the use of direct and indirect tests. Direct tests detect viable *Brucella* or *Brucella* DNA itself from samples whereas indirect

tests detect antibody or cellular responses. Direct tests include bacteriology and molecular methods and indirect tests serological and skin tests.

Antigens relevant to brucellosis diagnosis can be classified into two categories: S-LPS and protein antigens. The first category only elicits and/or reacts with antibodies whereas the second evokes both antibody and cell-mediated responses. S-LPS triggers the most intense antibody response in infections by S-brucellae, and in comparison proteins trigger only weak antibody responses.

S-LPS is in the outer membrane of the bacteria. Proteins are either in the outer-membrane, periplasm or cystoplasm. S-LPS is composed of lipid A (inserted in the outer membrane or OM) linked to a polysaccharide (PS) made of two sections: the core oligosaccharide and the O-polysaccharide (O-PS). In addition to the S-LPS O-polysaccharide, S brucellae produce a polysaccharide (native hapten [NH]) not linked to the core-lipid A that is structurally similar to the O-polysaccharide.

The S-LPS O-polysaccharides contain the epitopes relevant in diagnosis and serotyping. They are made of *N*-formyl-perosamine linked mostly in α 1-2 but with up to 20% of α 1-3 bonds. The distribution of these linkages creates three overlapping epitopes: A (abortus), M (melitensis) and C (including both A and M and common to all S-brucellae). It is important to note that: (a), despite their notation neither A nor M are characteristic of *B. abortus* or *B. melitensis* because their proportions vary depending on the biovar; and (b), C epitopes can be described as A>M, A=M or A<M depending on the degree and specificity of the overlapping. The O-PS cover the bacterial surface and antibodies of C reactivity (A>M, A=M, and A<M) are largely dominant in infection.

Serological tests cannot differentiate between infecting species of *Brucella* because the epitope combinations displayed by different S *Brucella* species and biovar display overlapping reactivity. *B. abortus* and *B. melitensis* S-LPS are similarly effective for the diagnosis of infections by the heterologous species no matter whether they are used purified or as bacterial suspensions. Moreover, serological tests do not identify the *Brucella* infecting species (Alton et al., 1988, Alonso-Urmeneta et al., 1998, Jacques et al., 1998, Tittarelli et al., 2005, OIE, 2009b).

The structural location of antigens in *Brucella* determine if antibodies can be detected by bacterial suspensions or extracts rich in envelope components or with periplasmic-cytosolic fractions or purified proteins. The topological arrangement of S-LPS makes the O-PS but not the core or the lipid A epitopes readily accessible to antibodies when using intact S bacteria as diagnostic antigens. Accordingly, tests performed with S *Brucella* cells detect mostly or only anti-O-PS antibodies.

Because they carry no surface charge (Schurig et al., 1981, Gonzalez et al., 2008), S-brucellae make stable suspensions suitable for agglutination tests (7.2.1.1.1 Blood serum agglutination tests). S brucellae do not activate the complement in an antibody-independent fashion (Barquero-Calvo et al., 2007), so they can be used in the complement fixation test (CFT) (7.2.1.1.3 Complement fixation test). Immunoprecipitation and immunosorbent tests use S-LPS or extracts rich in this molecule. Due to their amphipathic nature, S-LPS molecules aggregate into micelle-like supramolecular structures that mimic the bacterial surface exposing the O-PS and hiding the core oligosaccharide and lipid A epitopes (Shands, 1973, Leong et al., 1970). Immunoprecipitation tests with S-LPS mostly detect antibodies of O-PS specificity. This, and the large size of S-LPS aggregates, makes this test equivalent to an agglutination (micro-agglutination) test rather than a true precipitation test (Milgrom and Loza, 1967). Adsorption to hydrophobic plastics opens the S-LPS aggregates making the lipid A and core epitopes (also present in R or rough brucellae) accessible to antibodies. Relevant for immunosorbent assays in a context where rough vaccines such as RB51 are used, as vaccinated animals will test positive with such tests (Lamb et al., 1979, Nielsen et al., 2005, Barrio et al., 2009).

Brucella O-PS cross-reacts with the O-PS of a few gram-negative bacteria (e.g. *Yersinia enterocolitica* serotype O:9, *Escherichia coli* 0157, *Salmonella* group N [O:30]) which is a source of false positive serological reactions (FPSR). Cellular immunity tests, which rely on protein antigens, are not affected by specificity problems in the FPSR context (Perry and Bundle, 1990, Douglas and Palmer, 1988).

In the evolution of antibody response to S-LPS, IgG1 is the most important immunoglobulin isotype in animal brucellosis infection. The anti-S-LPS antibody response includes IgM, IgG1, IgG2 and low amounts of IgA. Hence tests that detect

IgM and/or IgG will have varying sensitivity based on the stage of infection. The disease in ruminants and humans gives rise to a first peak of agglutinating antibodies that are progressively substituted by non-agglutinating antibodies (Beh and Lascelles, 1973, Cho and Ingram, 1972, Unel et al., 1969). Non-agglutinating antibodies remain attached to bacteria that have not agglutinated and can be revealed using an anti-immunoglobulin serum that causes secondary agglutination (Coomb's test) (Beh and Lascelles, 1973, Cunningham, 1967, Beh, 1973). In cattle, agglutinating antibodies are IgM, IgG and IgA isotypes, and non-agglutinating antibodies are mostly part of IgG1 and the IgA serum fractions (Beh and Lascelles, 1973, Beh, 1973, Diaz and Levieux, 1972, Levieux, 1978, Wilkinson, 1966).

These characteristics of the antibody response to the S-LPS illustrate, first, that detection of IgG1 is essential in the serodiagnosis of cattle and small ruminant brucellosis, and, second, that there is a great similarity of response to wild type and S-vaccine strains. It is well known that this similarity reduces the specificity of tests after vaccination and that, despite early suggestions (Beh, 1974, Patterson et al., 1976), it is not possible to differentiate infected and vaccinated animals based on the presence/absence of specific classes or subclasses of anti-S-LPS immunoglobulins.

7.2.1 Serological diagnosis of infections by *S Brucella* species

Some serological tests used in the diagnosis of *Brucella* infections in animals have been found to be very sensitive (Greiner et al., 2009, EFSA, 2006). Antibody and cell-mediated responses, however, may not be detected during early stages of infection, in very old animals and in congenitally infected offspring. Moreover, not only infection but also vaccination and contact with *Brucella* or cross-reacting bacteria trigger immunoresponses to *Brucella* antigens. Sensitivity may be a problem in very old or young animals, and specificity in animals that have been in contact with *Brucella* but have cleared the infection and in the vaccination or FPSR contexts.

Rather than analytical sensitivity and specificity, it is the diagnostic sensitivity and specificity and the context where these two parameters are defined that matters (i.e. different cut-offs or antigen standardisation methods may apply in different contexts). Analytical sensitivity is the ability to detect minute amounts of an analyte (for example, specific antibodies). Diagnostic sensitivity and specificity (DSe and

DSp, respectively) denote, respectively, the ability to identify truly infected (no false-negative) and truly non-infected (no false-positive) subjects.

Sensitivity and specificity need assessment under the conditions of use, and these are variable (see 7.2.4.1 below). For example, non-infected animals in endemic areas commonly show low amounts of anti-*Brucella* antibodies so that they would be misdiagnosed as infected with the cut-off values established under the conditions of brucellosis-free countries. However, tests are also important in animal trade and the use of different cut-off values can be conflicting. Nevertheless, when used judiciously and with awareness of their properties, current tests are satisfactory to monitor the disease and to assist in eradication. An important aspect to keep in mind is the quality of the antigen and the method used for its standardization as different antigens have varying sensitivities depending on the way they were standardized.

7.2.1.1 S-LPS Antibody tests

A variety of S-LPS tests have been proposed but few are commonly used. Since none of the tests described below are vastly superior over others in terms of DSe and DSp (Greiner et al., 2009, EFSA, 2006), test selection should be based on infrastructure available, assay complexity, costs and the context where they are applied.

7.2.1.1.1 Blood serum agglutination tests- the Rose Bengal Test

This is a widely used, cheap and rapid plate agglutination test with a stained *B. abortus* suspension at pH 3.6-3.7 (Davies, 1971). Under these conditions, IgM and IgG (agglutinating and non-agglutinating antibodies)[7] are detected and the prozone[8] effect and unspecific agglutinations[9] that may occur occasionally at neutral pH disappear (Lamb et al., 1979, Morgan et al., 1969, Diaz and Levieux, 1972). These characteristics make RBT a highly sensitive and specific (up to 99% in some studies) test in cattle that can detect infection earlier than most existing tests (Patterson et al., 1976, Beh, 1973, Levieux, 1978, Plackett and Alton, 1975). The test is based on the principle that antibodies reacting with the O-PS on S *brucella* cells in suspension

[7] At neutral pH, some sera contain non-agglutinating antibodies, also known as 'blocking antibodies' that prevent binding of agglutinating antibodies
[8] At neutral pH, some sera that contain antibodies to *Brucella* S-LPS do not agglutinate the bacteria unless diluted
[9] At neutral pH, some IgM react non-specifically with *Brucella* cells

make the stain-tagged bacteria aggregate into clumps that become visible on a surface. Because it does not require automation or complex equipment, this test is easy to perform and appropriate for use in the resource-poor country context.

7.2.1.1.2 Milk agglutination tests- Ring test

The ring test was designed for testing cattle milk and is performed by mixing milk with a stained *B. abortus* suspension. Upon incubation at 37ºC, the bacteria bound to specific immunoglobulins (IgA but also IgM and IgG) appear in the cream layer, which looks like a blue ring. Depending on the number and quality of sample, the test is sensitive and easy to perform, and the conditions for testing pooled milk (i.e., sensitivity with regard to numbers of animals and total volume of sample) have been studied (Roepke and Stiles, 1970). However, development of the characteristic ring depends on the milk properties, in particular the content and type of fat. Thus, mastitis and other conditions affecting milk quality (e.g. colostrum) cause false positive results, and it lacks specificity in sheep, goats and possibly other ruminants. The MRT has been reported to be 68% sensitive in herds with positive blood serology and 88% sensitive in herds in which the reactor(s) were in production at the time of the test (Pietz, 1977). The test needs to be repeated three to four times a year for detection of infected herds rather than individual animals. This is gradually being replaced by a milk iELISA with S-LPS and IgG specific conjugate (IgG1 is dominant in ruminant milk) for optimal sensitivity. The analytic sensitivity is reportedly higher for the ELISA than for the milk ring test (Bercovich and Taaijke, 1990).

7.2.1.1.3 Complement fixation test

This test detects primarily IgG1 antibodies to the S-LPS of S *Brucella* cells by determining the consumption of guinea pig complement using a hemolytic (erythrocyte and anti-erythrocyte antibody) system. Although at least bovine IgM also activates guinea pig complement, this immunoglobulin is largely inactivated during the heat-inactivation of the serum performed before testing. Thus, this is a complex test and all components and steps require careful and periodical titration and standardization. The test is not adapted to the resource-poor context because of its complexity and the fact it is cumbersome to perform unless automated. CFT cannot be used in sera with anti-complementary activity or in haemolysed sera. In sheep,

CFT is less sensitive than standard RBT (Blasco et al., 1994a, Blasco et al., 1994b, Ferreira et al., 2003) but the results these two tests do not always coincide in infected animals. Therefore, RBT and CFT can be used together in sheep to obtain the best diagnostic sensitivity. CFT is less sensitive but more specific than RBT in S19 vaccinated or Rev 1 vaccinated animals (see below), so that it has been used as a confirmatory test in eradication programs (MacMillan, 1990). However, a "true" confirmatory serological test does not exist and it is always necessary to perform a close follow up of the situation in the herd or flock.

7.2.1.1.4 NH precipitation tests

Antibodies to NH can be detected by immunoprecipitation in a hypertonic agarose gel. For sensitivity (up to 92%), a reverse radial immunodiffusion format containing NH is recommended but double gel immunodiffusion is also useful (Diaz et al., 1979). Only two months after vaccination with S19 or Rev 1, these tests are highly specific in animals vaccinated and a positive result correlates with *Brucella* shedding (Diaz et al., 1981, Diaz-Aparicio et al., 1994, Jimenez de Bagues et al., 1992, Jones et al., 1980). Thus, although sometimes dismissed because they have sensitivity lower than ELISA or FPA (Nielsen, 2002), they are optimal when mass vaccination is implemented, a circumstance that severely affects the specificity of other tests. Similarly, these tests are not affected by the FPSR problem. The main problem is availability because NH is not marketed presently and, although there are simple preparation methods, they require a minimum of laboratory equipment.

7.2.1.1.5 Fluorescence polarisation assay (FPA)

This assay uses a *B. abortus* core-O-polysaccharide labeled with a fluorescent molecule. The free rotation of core-O-polysaccharide in suspension decreases upon antibody binding and causes an increase in polarized light intensity in the vertical and horizontal planes. Measurements (in millipolarization units, mP) can be performed in minutes with diluted serum and, presumably, with milk or even blood. The performance of FPA in cattle in the absence of S19 vaccination is similar to that of indirect enzyme linked immunosorbent assay (iELISA) and RBT, and this probably applies also to sheep and goats (Minas et al., 2007, Ramirez-Pfeiffer et al., 2007). Some studies suggest that FPA has specificity greater than that of other S-

LPS in S19 vaccinated cattle (Aguirre et al., 2002). Further studies are required in sheep. Although simple, FPA requires a well-calibrated fluorescence polarization analyzer and assessment under local conditions. As for primary binding assays (see below), it is not only the O- polysaccharide but also the core antigens which are exposed. FPA, therefore, detects anti-R-LPS antibodies such as those produced by RB51 and other R vaccines or, in sheep, by *B. ovis* infections.

7.2.1.1.6 Primary binding assays

7.2.1.1.6.1 iELISA

The literature describes several iELISA protocols that use S-LPS or core-O-polysaccharide coated polystyrene multi-well plates and several anti-IgG or protein G-conjugates. They can be applied to blood or milk serum, and commercial kits are available. Under experimental conditions, the sensitivity of some iELISAs is equal or higher than that of RBT and higher than that of the CFT and, since they can be automated, there is a trend in countries with good laboratory facilities to replace the classical tests by iELISA for surveillance purposes. Like all S-LPS tests, iELISAs are affected by vaccination with S19 or Rev1 and by FPSR. Moreover, absorption destroys S-LPS supramolecular structure and the core lipid A epitopes become accessible to antibodies in iELISAs. Therefore, contrary to RBT and CFT, iELISAs detect anti-R-LPS antibodies such as those produced by RB51 and other R vaccines or, in sheep, by *B. ovis* infections (Barrio et al., 2009, Mainar-Jaime et al., 2008).

7.2.1.1.6.2 cELISA

In cELISAs, a monoclonal antibody of C specificity is adjusted to compete with antibodies resulting from vaccination or infections due to cross-reacting bacteria, both of which are presumed to be of lower average avidity/titer than those resulting from infection. Since there is no immunoglobulin-specific conjugate, cELISA is theoretically multi-species. However, there are conflicting results on its sensitivity in cattle (Munoz et al., 2005, Nielsen, 2002) and cELISA does not resolve the FPSR problem. In sheep, it does not outperform CFT and has lower sensitivity than RBT (Marin et al., 1999, Minas et al., 2008). Similar to iELISA, the specificity of cELISA is compromised by vaccination with Rev 1, S19 or RB51.

7.2.1.1.6.3 Lateral flow immunochromatography assay

This assay was developed for human brucellosis and then adapted to animal brucellosis (Abdoel et al., 2008). It uses a chromatographic device made of a sample pad, a conjugate pads and a detection strip of porous nitrocellulose, all in a plastic enclosure. Small amounts of serum (or blood) and of a developing buffer are placed on the sample pad, which delivers the mixture to the conjugate pad. The latter contains a colloidal gold anti-ruminant IgG conjugate in a dry matrix that, when dissolved, allows the conjugate to react with the IgG in the sample. The liquid flows into the detection strip where a transversal line with adsorbed S-LPS captures the complexes containing anti-S-LPS IgG producing a line with the red colour of colloidal gold. The complexes lacking specific IgG migrate further to be captured in a second line by anti-IgG antibodies. This results in a second red line indicating that the assay has worked correctly (Abdoel et al., 2008). LFA is simple with the potential of being used as a penside test for serum and blood. Preparation requires sophisticated equipment and, at least the human version, presents reproducibility problems (R. Conde-Álvarez, R. Díaz and I. Moriyón; unpublished observations).

7.2.1.2 Protein tests

Proteins differ from S-LPS in that: (a), they elicit both antibodies and cellular immunity; (b), the antibody response to proteins is delayed with respect to S-LPS; (c), there is no single immunodominant protein; and (d), no cross-reactivity exists with significant pathogens so that proteins tests do not produce FPSR.

Protein-rich extracts (brucellin or Brucellergene and cytosoluble fractions) devoid of S-LPS or O-polysaccharide are appropriate for testing cellular immunity (Garin-Bastuji et al., 1998, Saegerman et al., 1999). The corresponding intradermal skin-test is highly specific but has moderate sensitivity for individual diagnosis and remains positive for years in some vaccinated animals (Fensterbank, 1984). However, it is negative in animals that show FPSR and may thus be useful at herd/flock level (MacDiarmid, 1988). These protein fractions give poor results in ELISA. A protein that has been investigated in detail is *B. abortus* and *B. melitensis* BP26 but the sensitivity is not adequate (Grillo et al., 2009, Rossetti et al., 1996).

7.2.1.3 Bacteriology

Stamp's staining of smears of vaginal swabs, placentas or aborted fetuses can shows bacteria morphologically similar to *Brucella* but isolation is the only unequivocal diagnostic method. Bacteriological isolation is performed to confirm the disease and to determine the *Brucella* species. The technique is considered as the gold standard against which other tests should be assessed, but may lack sensitivity.

7.2.1.4 Molecular tests

Molecular methods such as Bruce-ladder allow a more robust typing at species and, in some cases, biovar level (Lopez-Goni et al., 2011, Lopez-Goni et al., 2008). Several PCR protocols have been optimized in laboratory experiments for analytical sensitivity and specificity, but there are few studies on diagnostic performance. The variety of samples, DNA extraction and PCR protocols, limitations intrinsic to the type of samples, and that reference bacteriological or serological procedures are not uniform or optimal complicate diagnostic development. While not currently applied for routine diagnosis, they are valuable for epidemiological purposes. Molecular tests species, biovar and vaccine typing and can be applied to colonies on isolation plates avoiding dangerous manipulations. Some tests are presented in Table 62. Whereas most identify the species, this is not always the case with the classical biovars. Part of the discrepancy stems from the reproducibility problems of the classical typing. Many strains grouped by classical typing do not always reflect an epidemiological situation or outbreak, and some molecular methods reveal these inconsistencies. Methods like Bruce-ladder for species identification or MLVA for finer analyses (Table 62) will probably be used extensively in the future.

Molecular tests are run on bacteria isolated through bacteriology, and this limits their widespread use as bacteriology is expensive, time consuming and cumbersome. A recent paper has described running a VNTR directly on field samples, which can be useful for epidemiological purposes (Gopaul et al., 2014). However, the actual diagnostic value in terms of DSe and DSp remains to be determined.

Identification level	Test	Description (references)
Species	AMOS-PCR	A multiplex PCR assay based on IS711-related polymorphism that differentiates *B. abortus* (biovars 1, 2, and 4), *B. melitensis* (biovars 1, 2, and 3), *B. ovis*, *B. suis* (biovar 1), plus vaccines *B. abortus* S19 and RBT51 (Bricker et al., 2003b)
	Bruce-ladder-PCR	A single-step multiplex PCR assay that identifies *B. abortus* biovars 3, 5, 6, 7, 9, *B. melitensis*, *B. ovis*, *B. suis* biovars 2, 3, 4, *B. canis, B. neotomae*, *B. pinnipedialis* and *B. ceti* as well as the vaccine strains *B. abortus* S19, *B. abortus* RBT51 and *B. melitensis* Rev.1. It is based on gene polymorphism specific of each species. Some *B. canis* strains can be identified erroneously as *B. suis.* (Lopez-Goni et al., 2008)
	MLSA-SNP	Based on multilocus sequence analysis (MLSA) (Whatmore et al., 2007b), the method detects single nucleotide polymorphism (SNP) by sequencing of DNA obtained in a multiplex SNP-primer extension protocol. MLSA-SNP identifies the six classical *Brucella* species plus the marine strains as a group (Scott et al., 2007)
Species and strain	MLVA-16	A PCR format for multiple locus variable number tandem repeats (VNTR) analysis (MLVA) developed on a previous similar method (MLVA-15;(Le Fleche et al., 2006). It uses a set of 8 minisatellite markers to discriminate *Brucella* species, including *B. microti*, plus a second set of 8 microsatellite markers for fine discrimination (Al Dahouk et al., 2007, Scholz et al., 2008).
Strain	HOOF prints	Method based on multilocus hypervariable octameric oligonucleotide fingerprints (HOOF) analysis. It is highly discriminatory in both a spatial (different locations) and a temporal (i.e. repeated isolation from the same animal or flock) fashion and therefore it may useful for epidemiological studies but does not provide species identification (Bricker et al., 2003a)

Table 62 Some molecular tests for Brucella identification and typing (Zinsstag et al., 2011b)

7.2.2 Brucellosis diagnostic tests for humans

The clinical manifestations of human brucellosis are variable and unspecific and a keen awareness of possible infection and occupational history are necessary to reach a suspicion of brucellosis. In turn, this requires confirmation using laboratory tests.

7.2.2.1 Antibody tests

Serological tests (Table 63) are useful for human brucellosis and some are affordable. They must be interpreted in light of clinical symptoms compatible with brucellosis because brucellae contact is not necessarily followed by infection.

Slaughterhouse workers and veterinarians may present anti-*Brucella* antibodies but no clinical infection. Antibodies can persist long after recovery in many individuals. Seroconversion is seldom observed and is a poor diagnostic criterion since incubation can be long. Control quality of the antigens is of paramount importance.

In human brucellosis, antibodies have been described as agglutinating, non-agglutinating and blocking (i.e. those that block the agglutinating antibodies) depending upon their activity in the serum agglutination test. Although IgM, IgG and IgA are agglutinating antibodies, some IgG and IgA subsets are non-agglutinating. The blocking activity is related to the prozone phenomenon in the serum agglutination test and is of little practical relevance. The serum agglutination test in tube (or the simple slide agglutination test) cannot be recommended as the only test because of the dominancy or non-agglutinating antibodies in brucellosis of medium to long evolution. The Coombs test performed after SAT detects the non-agglutinating antibodies when they exist so that the SAT-Coombs combination can be used to assess the time of evolution (from high SAT titers and negative Coombs in acute cases to negative SAT and high Coombs titers in long evolution cases). Alternatively, non-agglutinating antibodies become agglutinating at pH $\leq$ 5, and can be detected by Brucellacapt® and RBT so that both are useful no matter the time of evolution of the disease. RBT is cheap and simultaneously useful in animal brucellosis. RBT is often considered a qualitative test (positive or negative) not fully effective in discriminating exposure from active infection in endemic areas. However, both problems are largely overcome when RBT is used to test serum dilutions to obtain a diagnostic titer. Thus, RBT is the test of choice in rural settings and in small or understaffed hospitals. The human version of LFA, although expensive, is simple and allows determination of IgM and IgG and thus assessment of the state of evolution of the infection (Díaz et al., 2011). However, the kit presents serious reproducibility problems (R. Conde-Álvarez, R. Díaz and I. Moriyón; unpublished observations). There are several iELISAs available that, theoretically, can also provide information on the IgM/IgG ratios but they are affected by the same standardization and cut-off problems as the animal tests (see 7.2.3 below).

Test	Antibody detected	Diagnostic titer	Comments
RBT	IgM/IgG/IgA	Qualitative (but see comments)	Simple and affordable. In endemic areas, titers of 4 or lower may indicate "contact"
LFA	IgM or IgG	Qualitative and semi-quantitative	Simple and informative. The intensity of the reaction can be scored from 1 (weak) to 4 (strong).
SAT	IgM and agglutinating IgG/IgA	≥ 160	Simple; titers decrease and become negative with time of evolution
Coombs	Non-agglutinating IgG/IgA	≥ twice SAT titer	Relatively sophisticated; titers increase with time of evolution
Brucellacapt	IgM/IgG/IgA	≥ 160-320	Simple; titers increase with time of evolution
iELISA	IgM and/or IgG (depending upon conjugate)	(It does not apply)	Kits recommend OD cut-off values but these have to checked under the conditions of use

Table 63 Some serological tests used in the diagnosis of human brucellosis

7.2.2.2 Bacteriology

Cultures should be performed whenever possible and preferably in the pyretic phase. Isolation can be attempted from articular, cerebrospinal and other fluids or some tissues in focal forms but blood culture under 10% CO_2 is the routine method. Since growth is not visually perceived and repeated subculturing on agar media to isolate the microorganism is highly risky, modern bacterial growth detecting systems or Ruiz-Castañeda's biphasic system is recommended. In either case, prolonged incubation (up to 21 and 45 days, respectively) is necessary before discarding a suspicious culture. Large (5–10 ml) samples in duplicate flasks and two or three independent blood samplings at adequate intervals are advisable. The leukocyte lysis-concentration procedure or the use of bone marrow may improve detection. Rates of isolation can be high (up to 86%) in the pyretic phase, less in apyretic intervals. Indeed, when antibiotic treatment is applied before culturing, the success is low. Unless infection by Rev 1 or RB51 is suspected,[10] identification to genus level is enough for medical purposes and the species is not a factor in choosing the treatment (Díaz and Moriyón, 1989). PCR-based methods have been developed to

[10] Rev 1 is streptomycin (but not gentamycin)-resistant, and RB51 is rifampin- resistant. Therefore, these antibiotics (normally used in brucellosis treatment) cannot be used in these infections.

detect *Brucella* DNA in human samples but the variety of protocols and reproducibility problems preclude any recommendation.

7.2.3 Brucellosis test standardization

The need for standardized tests that use biological reagents (complement, antisera, labelled antigens, conjugates, etc.) is clear. However, as S-brucellae are prone to undergo drifts in surface structure that both removes the major S-LPS epitopes and cause unspecific serological reactions, standardization of brucellosis tests has traditionally emphasized antigen quality. For RBT, SAT, CFT, and iELISA, protocols are set by the OIE, the core of which is antigen calibration against the second OIE International Standard Serum (OIEISS) (OIE, 2009a). Serum (obtained from a cow inoculated with *B. abortus* which had remained infected for six years (Davidson et al., 1969) is defined as containing 1000 international SAT units or 1000 international CFT units per mL. S-*Brucella* suspensions are adjusted to produce 50% agglutination (SAT) with a 1/600-1/1000 dilution of the OIEISS (or 75% with a dilution of 1/500 -1/750) and a 50% haemolysis (CFT) at a 1/200 dilution (Davidson et al., 1969, OIE, 2009a). Since it is a qualitative test, no RBT units are assigned to the OIEISS, and the bacterial suspension at pH 3.7 is adjusted to give a clearly positive reaction with the 1/45 but not with the 1/55 dilution of the OIEISS. For bovine ELISA, a strong and a weak positive (actually a dilution of the former) sera derived from the OIEISS plus a negative serum are recommended (OIE, 2009a). In addition, there is an International Standard anti-*Brucella melitensis* Serum (ISaBmS). It has been argued that, because the OIEISS is an anti-*B. abortus* serum, it is not suitable for use in assays such as iELISA for species other than cattle (McGiven et al., 2011). Following this reasoning, the sera of 7 naturally infected goats and of 4 goats experimentally infected with two *B. melitensis* serovars bled at various intervals were pooled and heat-inactivated (McGiven et al., 2011). This ISaBmS has been used to adopt consensus criteria to standardize antigens for sheep and goat tests following the same approach as for the OIEISS, i.e., to adjust the assays so that a low and a high dilution of the ISaBmS give respectively a positive and a negative result (1/64 and 1/750 for iELISA; 1/8 and 1/300 for cELISA, 1/16 and 1/200 for FPA and 1/16 and 1/200 for RBT). However, for technical reasons, the OIEISS remains the primary standard for RBT and CFT (McGiven et al., 2011).

It is important to understand that, however valuable for antigen standardization, these protocols meet primarily one of the needs of international trade (i.e. harmonization) and do not imply a diagnostic cut-off (McGiven et al., 2011, OIE, 2009a). The OIEISS is a snapshot of the antibody response over time, and shows the agglutinating and complement fixing (IgG1) antibody levels (Davidson and Hebert, 1978) typical of long evolution brucellosis. The ISaBmS does not overcome this limitation because a heat-inactivated pool is not representative of the variable isotype ratios of individuals in the successive stages of the infection. Therefore, concerning the DSe of tests, neither the OIEISS nor the ISaBmS can substitute for a panel of positive sera representing the variable isotype levels. Moreover, the standardization protocols do not include a panel of negative sera but rather rely on dilutions of a positive serum. Therefore, they set a limit to the analytical sensitivity (in a broad sense, because IgM, IgG and IgA are different analytes) (McGiven et al., 2011) that may be above the threshold necessary for optimal DSe, as has been shown to happen for RBT and CFT in small ruminants. Indeed, as discussed below, the cut-off set by the positive control dilutions of the ISaBmS in ELISA (1/300) and FPA (1/200), or the negative serum in bovine ELISA, does not necessarily correspond to the diagnostic cut-off, a clear problem in the direct use of commercial kits.

7.2.4 The validation of brucellosis serological tests

Validation is the evaluation of a process to determine its fitness for a particular use. For a serological diagnostic test, this is ability to identify the presence of a particular antibody and to allow making predictions about the status of the test subject. This ability depends on a number of variables that affect the sample (e.g. age, sex, breed, nutritional status, pregnancy, immunological responsiveness, exposure to the pathogen, cross-reactive antibodies), the assay system (e.g. instrumentation and technician error, reagent choice and calibration, accuracy of controls, water, diluents and buffers quality, incubation temperatures and durations) and the capacity of a test result to predict accurately the status of the host (which depends on DSe and DSp and on the prevalence in the target population) (Jacobson, 1996).

7.2.4.1 Diagnostic sensitivity and specificity in brucellosis tests

For DSe and DSp it is obvious that cut-offs must be optimized for quantitative tests and that for this purpose it is necessary to use sufficient numbers of truly infected and pathogen-free animals (Jacobson, 1996). For brucellosis, to meet these two requirements is problematic. The use of a Gaussian distribution (cut-off value defined as the mean plus two standard deviations of negative reference samples) is not adequate for brucellosis because test values follow a skewed distribution, and the procedure does not consider the DSe (Greiner et al., 2000). Since in general as sensitivity increases specificity decreases and vice versa, the receiver operator characteristic (ROC) method (based on plots of 1- DSe against 1-DSp for all cut-off values) is invaluable for DSe and DSp assessment (Greiner et al., 2000). It has to be stressed that use of the results of this analysis without a good understanding of the disease and the specific purpose of the test can be misleading. For example, brucellosis ROC analysis has been used to adjust cut-offs to yield the maximal combined DSe and DSp as J (or Youden; DSe+DSp-1) or performance [%DSe+%DSp] indexes and the values applied to the comparison of tests (Gall and Nielsen, 2004, Nielsen, 2002, Poester et al., 2010, Ramirez-Pfeiffer et al., 2007). However, such comparisons are not meaningful. Indeed, because brucellosis does not spread epizootically, under most circumstances early detection is not as critical as in highly transmissible epidemic diseases. Moreover, diagnosis is usually interpreted on a herd/flock rather than an individual basis and it is repeated over time, which facilitates the detection of infected animals. Thus, a relative lack of DSe can be acceptable. On the other hand, imperfect DSp generates unnecessary culling and the ensuing conflicts with farmers, needless quarantines, plus trade and policy problems, so that the starting criterion for test selection should be 100% DSp, and then maximal possible DSe. This is clearly true of at least the last stages of eradication and of surveillance in brucellosis-free areas where FPSR occur.

DSe and DSp are population-specific, the main reason being the existence of biological factors that are not equal in different populations (Greiner and Gardner, 2000). In brucellosis, such factors include management, male/female ratios and age distribution, animal breed, differences in reproductive periods, repeated exposure to

the pathogen in endemic areas, and variable degrees of exposure to cross-reacting bacteria. Owing to all these factors, sera from *Brucella*-free animals can produce significantly different background reactivity depending upon their origin. It is also worth commenting that, because of differences in analytical sensitivity and threshold affinity of tests as well as in the avidity of the antibodies resulting from infection or causing background reactivity, not all tests are similarly affected. For example, whereas RBT, CFT, NH-RID and protein immunoprecipitation all showed good DSp/DSe in Northern Spain goats, large discrepancies were found between the S-LPS tests, on one hand, and NH and protein tests, on the other, in Tunisian goats (Diaz-Aparicio et al., 1994). Indeed, a frequent observation in tropical veterinary medicine is the decrease of specificity in the target population of tests previously "validated" using non-exposed populations (Greiner and Gardner, 2000, Jacobson, 1996). Therefore, cut-offs obtained with animals from *Brucella*-free countries and infected animals from endemic areas as negative and positive controls, respectively, (Nielsen et al., 1998, Nielsen et al., 2001, Nielsen et al., 2004a, Nielsen et al., 2004b, Nielsen et al., 2007) must be interpreted bearing in mind this problem.

7.2.4.2 Definition of *Brucella*-infected individuals for test evaluation

"Gold standard" methods (i.e. those that identify truly infected animals) include the unequivocal isolation of the agent and pathognomonic criteria (Jacobson, 1996) but, as the latter is not applicable in this disease, the former is the only gold standard in animal brucellosis. However, some workers argue that *Brucella* isolation is intrinsically insensitive and that bacteriologically positive animals are not representative of the infected population (Fosgate et al., 2006, Muma et al., 2007b, Minas et al., 2005, Minas et al., 2007, Minas et al., 2008). Indeed, bacteriology sensitivity is low when performed incorrectly but long experience shows that, when the aim is to identify all possibly infected animals, *Brucella* is isolated from over 80 or even 90% of individuals, including cases with low or negative serological results (Nelson et al., 1966, Blasco et al., 1994b, Diaz-Aparicio et al., 1994, Hornitzky and Searson, 1986, Huber and Nicoletti, 1986, O'Grady et al., 2014). This requires the right medium or media combination (Corner et al., 1985, de Miguel et al., 2011, Hornitzky and Searson, 1986, Marin et al., 1996), a thorough examination of a

sufficiently large number of plates, the inoculation of aliquots considerably larger than those used for other purposes (Blasco et al., 1994b), and appropriate samples. In live animals, the latter are vaginal swabs (taken shortly after abortion), semen, aborted fetuses and fetal membranes and milk. In abattoirs (or after necropsy), retropharingeal and mammary lymph nodes (about 80% of adult infected cattle, sheep and goats develop infections in these nodes) and spleen are optimal (Blasco et al., 1994b, Hornitzky and Searson, 1986, Nelson et al., 1966, Corner et al., 1987, Marin et al., 1996, O'Grady et al., 2014). Culturing other lymph nodes, the uterus of pregnant or early post-parturient animals and the male reproductive organs and sex glands, and any tissues showing inflammatory lesions and abscesses can further increase sensitivity. Regrettably, only a handful of studies that use this gold standard describe the bacteriological methodology (Blasco et al., 1994b, Diaz-Aparicio et al., 1994, Hornitzky and Searson, 1986, O'Grady et al., 2014, Huber and Nicoletti, 1986), which makes an appraisal of the conclusions of many other works difficult. Moreover, in some studies the animals sampled for culture were selected by a previous positive serological result (Minas et al., 2005), which biases DSe and DSp estimates. It is clear that culture is not useful to evaluate DSp, if properly conducted, it is the gold standard for assessing the DSe of indirect tests. However, because the gold standard may be difficult to obtain, reliable assays can be used as relative standards even though the results are compromised by the fact that the error in DSe and DSp estimates of the relative standard is carried over (Jacobson, 1996).

7.2.4.3 Latent-Class analysis

Bacteriology is cumbersome, expensive and requires proper infrastructure and is seldom applicable for the evaluation of brucellosis tests under the conditions of many developing countries. An attractive alternative are Latent-Class analysis models that use maximum likelihood or Bayesian approaches to obtain DSe and DSp and prevalence estimates when the status of individuals is unknown. These models rely on several assumptions and on the premise that researchers have prior knowledge on the DSe/DSe and prevalence, and update this prior knowledge using new data collected during the study. Indeed, both the soundness of the assumptions and the quality of the priors have important consequences on the estimations. The most solid

set of assumptions (the so-called Hui-Walter paradigm) are (i) that the population is divided into two or more populations in which two or more tests are evaluated, (ii) that the DSe and DSp of the tests are the same in all populations, and (iii) that the tests are conditionally independent. Assumption (i) can be supported by a good experimental design according to statistical rules for the number of tests-populations included in the analysis (which nonetheless is not always the case). Assumptions (ii) and (iii) are more difficult to meet. Toft et al. (2005) evaluated the impact of deviations of these assumptions; their conclusions are discussed below in the context of brucellosis and brucellosis tests.

A difference in the DSe and DSp of a given test between populations may result in estimates that are biased towards the DSe or DSp of the test in the population with highest or lowest disease prevalence, respectively. As discussed above, DSe and DSp (and cut-offs) are population-specific and, moreover, brucellosis prevalence often varies from urban to rural settings, and is affected by the kind of management (intensive or extensive broadly speaking), herd composition, and other variables (Racloz et al., 2013). Therefore, priors obtained under one of these conditions cannot be directly extrapolated to others. Also, priors of brucellosis seroprevalence should also be chosen according to the specific test(s) because different tests detect different (or overlapping) antibody classes and/or activities. Furthermore, as both antibody classes and/or activities evolve during the course of the infection, the picture offered by different tests depends on the rate of transmission, which varies depending not only upon stock density and management (Racloz et al., 2013) but also on season and climate. Finally, for some brucellosis tests, such as CFT, iELISA and cELISA, there are significant variations in the protocols so that DSe/DSp (and prevalence) priors must be selected taking also into account homogeneity of the technical aspects of the tests. These variables have seldom (if ever) been considered when Latent-Class analysis methods have been applied in brucellosis DSe/DSp and prevalence studies.

Concerning conditional independence, Toft et al. (2005) stress that, in general, this assumption cannot be relaxed without posing serious problems to the estimation procedure as this leads to modelling with additional and not always obvious assumptions. It is generally accepted that conditional independence is fulfilled when

tests measure different physiological phenomena. This criterion cannot be applied to the antibody versus cell-mediated immune responses because, as brucellosis triggers both, a positive result in a test detecting the former predicts that a test detecting the second is highly likely to be positive, as experience shows. Similarly, there is correlation between the antibody response to proteins and S-LPS so that a positive protein test makes highly probable a positive S-LPS test. Most tests detect antibodies to the S-LPS and, although this suggests conditional dependence, the issue is complicated by the fact that tests differ in the immunoglobulin isotypes and/or activities detected and that these are not constant during the course of the infection. For example, while two tests that measure exclusively anti-S-LPS IgG1 (such as CFT and some iELISA) show constant conditional dependence in all serum samples, this may be or not the case of SAT, RBT and iELISA (and possibly cELISA and FPA) depending upon the time of infection. Therefore, even the assumption of conditional dependence can be a misrepresentation of the biological reality if the tests are not selected on a good understanding of their characteristics. Indeed, different authors consider the same brucellosis S-LPS tests as conditionally dependent or independent following superficial assumptions that do not take into account the above-summarized facts (Muma et al., 2007b, Sanogo et al., 2013b).

7.3 Diagnostic tests used in the KGR

7.3.1 Choice of tests

The choice of test is dictated by its ability to simultaneously detect infected animals (few false negative results, high sensitivity) without giving positive results in uninfected animals (few false positive results, high specificity). The selection also depends on the context with regards to presence of vaccination (both with smooth or rough vaccines), a source of unspecificity. Cross-reacting bacteria can also cause unspecific cross-reactions. Selection of quantitative tests and the cut-off set must be carefully considered and tailored to the epidemiological context (endemic versus *Brucella*-free context), as cut-offs will affect the sensitivity and specificity of the test. The technical difficulty and repeatability of the test (robustness), as well as cost, suitability for automation, availability of antigens and reagents and the type of sample and species on which the test can be used are also important to consider.

Serological tests for brucellosis screening of cattle, sheep, goats and humans and number of individuals screened for each survey (March, June and October) are shown in Table 64. RBT was used for brucellosis diagnosis in KGR for all species. Bacteriological isolation and strain identification was performed for cattle isolates.

7.3.1.1 Cattle and small ruminants

7.3.1.1.1 Which S-LPS test to use?

Greiner et al. (2009) and EFSA (2006) performed a meta-analytic equivalence study on diagnostic tests for bovine brucellosis and a review of performance of brucellosis diagnostic methods for ruminants respectively. The study results were subjected to stringent inclusion criteria, and had to: (a) provide information on DSe and/or DSp of an approved or candidate test for testing individual cattle for brucellosis, (b) relate to a test standardised in accordance with international requirements or as prescribed by the supplier, (c) relate to non-vaccinated cattle, (d) relate to a EU-relevant *Brucella* strain, (e) consider sampling dates between 2 and 24 weeks after inoculation when estimating DSe in an experimental setting, (f) relate to animals sampled from an officially brucellosis free herd when estimating DSp in a non-experimental setting and (g) be published/submitted after 1970 (to exclude outdated diagnostic technologies) and in addition, (h) no iELISA results prior to 1990 were considered (this is the date iELISA has been standardised in the EU) (Greiner et al., 2009).

Although these reviews use only studies performed in EU animals and are thereby less relevant for the SSA context, they are the only reliable and robust comparison of sensitivity and specificity of EU-approved diagnostic tests for brucellosis. Greiner et al. (2009) conclude that S-LPS tests outperform all other tests and that RBT performs as well as other S-LPS tests in cattle, with a sensitivity of 98.1% (96.8-99.1%, 95% CI) and specificity of 99.8% (99.7-99.8%, 95% CI) in contexts where vaccination is not practiced. RBT is the recommended single test when vaccination has not been implemented (as in KGR). These conclusions obtained with well-defined populations are in sharp contrast with those of a Bayesian analysis performed with sera of animals of unknown status of Ivory Coast that reported 96.1%, and 54.9% sensitivity for the RBT and iELISA, respectively (Sanogo et al., 2013b). Using a similar approach in Zambia, Muma et al. (2007b) concluded that RBT was superior to

cELISA and FPA when the DSe/DSp combined were considered [the highest DSe was achieved by the cELISA (97%) and the highest DSp by the FPA (93%), conversely, these tests also had the lowest Sp and Se, respectively, with the RBT performing well in both the Se (93%) and Sp (81%)].

The modified protocol of the RBT (3:1 ratio of serum to antigen) has been reported to give high sensitivity (94%) and specificity (100% in the absence of vaccination) (Blasco et al., 1994b, Diaz-Aparicio et al., 1994) for the diagnosis of brucellosis in small ruminants. The standard RBT (1:1 ratio of serum to antigen) was selected as a standard test of high sensitivity and specificity in small ruminants by (EFSA, 2006).

In addition to its high sensitivity and specificity, the test is simple to perform and requires only basic equipment and materials (white tile, micro-pipette, toothpick etc.), useful for application in the resource-poor context and under field conditions. Sensitivity is optimised as the buffered conditions prevent pro-zoning and blocking phenomena and enable non-agglutinating antibodies (characteristic of long evolution brucellosis) to be detected. The test is cheap, costing 5 cents of a euro per test, compared to FPA (10$), LFA (5$), cELISA (6$) and iELISA (5$).

7.3.1.1.2 Why not use a milk S-LPS test?

Blood serological tests were chosen over milk serology for several reasons. Firstly, blood was already being collected for trypanosomiasis screening. Secondly, MRT, an affordable milk test, is a herd test that would provide estimates of individual prevalence. Thirdly, MRT performance is affected by mastitis and the California milk test showed 75% of individual animal milk samples collected from KGR cattle as mastitic and finally, MRT lacks specificity in small ruminants.

7.3.1.1.3 Why not use protein tests?

Antibody protein tests are not sensitive and there is a general lack of knowledge on how they work in the field. Cut-offs for DTH tests have not been validated.

7.3.1.1.4 Why not use primary binding assays?

The issue with quantitative tests such as the iELISA, cELISA or FPA, apart from their high cost and need for expensive equipment, is the influence of cut-off. Cut-offs for in-lab ELISAs have been defined for use in the *Brucella*-free European or

North American context to optimise sensitivity. Commercial ELISA kits are standardised for repeatability using OIE sera but require validation and for cut-offs to be established by individual labs using ROC curves for specific epidemiological contexts/regions in SSA (see 7.2.3 and 7.2.4 above).

7.3.1.1.5 Why not use an NH test?

NH tests provide better specificity in vaccinated animals. Vaccination is not practised in the KGR and this test has a lower sensitivity than RBT.

7.3.1.1.6 Potential problems with RBT

For RBT the quality and standardization of the antigen can be variable, which can lower sensitivity (to approximately 85%) but will not affect specificity (Blasco et al., 1994a; MacMillan, 1997). Factors affecting quality include S-R dissociation and incorrect bacterial concentration. This was minimised by using the CITA antigen, which instead of being standardized against the OIE serum (with an arbitrarily limited analytical sensitivity) is standardised according to gold standard positive and negative sera (and, therefore, for DSe and DSp). However, since the test is adjusted to diagnostic laboratories in Europe, problems may arise during its use under field conditions or because of small variations in the protocol (e.g.: temperature, timing).

7.3.1.1.7 Why use bacteriology and molecular typing?

The rationale for performing bacteriological isolation from cattle samples was firstly to confirm the presence of *Brucella* in the KGR. This was especially pertinent because of the above uncertainties with regards to performance of the RBT under conditions in Nigeria. The second objective was to determine the infecting species and biovar of circulating strains, as this has relevance for pathogenicity and propensity for transmission to humans and other hosts.

7.3.1.2 Humans

The diagnosis of human brucellosis by serology must take into account that there are persons that develop antibodies upon contact with the bacterium but do not become infected. A thorough clinical examination and the presence of symptoms compatible with brucellosis are essential to interpret the results of any brucellosis serological

test. Whilst clinical examination of all individuals sampled was beyond the scope of the study, all subjects were asked about experience of recurrent fevers.

7.3.1.2.1 Why use RBT?

The RBT was selected because of its high sensitivity (almost 100%) and specificity. Weak reactions may occur with sera from healthy persons in contact with infected animals or in patients after recovery, especially in endemic areas. This was partially solved by adapting the protocol to test serum dilutions. Titres equal to or higher than 1/8 correlate with active brucellosis; titres 1/2 and 1/4 must be considered, taking into account the presence/absence of clinical symptoms (Díaz et al., 2011). RBT was selected as a rapid, cheap qualitative/semi-quantitative test to detect agglutinating and non-agglutinating antibodies and is not affected by prozone or blocking effects.

7.3.1.2.2 Why use complementary tests?

Tests complementary to RBT were selected to ensure that 'suspicious' samples giving atypical or strange clumping reactions upon rescreening (see 7.3.4.2 below) were definitively negative. SAT and Coomb's tests were selected as they can differentiate between the acute or chronic phase of infection. SAT titres decrease and become negative with time of evolution whilst Coombs titres increase with time. The SAT detects agglutinating antibodies only (IgM mainly, some IgG and IgA), whilst the coombs detects non-agglutinating antibodies only (IgG and IgA).

Brucellacapt® is performed at pH 5.0 and thereby detects non-agglutinating antibodies and experiences no prozone or blocking effects. Because it is a quantitative test it also generates titres above which a diagnosis of brucellosis can be made. This test has the advantages of the RBT but is very expensive.

7.3.1.3 Test Summary

Protein tests are not as good as S-LPS tests; all S-LPS tests have a problem of specificity if *Yersinia enterocolitica* O:9 is present, but are similar in this regard; and finally all tests have problem of standardisation and adaptation to local conditions. Despite these limitations, the choice tests for this study was based on performance, cost and suitability for use under field conditions.

Test	*Conditions*	*Abbreviation*	*Antigen*	*Protocol/sera*	*Number sera* March survey	June survey	October survey	TOTAL
Cattle								
RBT	Field	FsRB	CITA	standard	1724	1972	0	3696
	NVRI lab	NsRB	CITA	standard	0	1972	0	1972
	UNAV lab (1)	UsRB	CITA	standard	0	200	0	200
Sheep								
RBT	Field	FsRB	CITA	standard	275	119	718	1112
	UNAV lab (2)	UsRB	CITA	standard	0	0	683	683
	UNAV lab (2)	UmRB	CITA	modified	0	0	695	695
Goat								
RBT	Field	FsRB	CITA	standard	79	0	779	858
	UNAV lab (2)	UsRB	CITA	standard	0	0	761	761
	UNAV lab (2)	UmRB	CITA	modified	0	0	739	739
Humans								
RBT	Field	FsRB	CITA	standard	0	0	1125	1125
	UNAV lab (2)	UsRB	CITA	standard	0	0	978	978
	UNAV lab (3)	UsRB	CITA	Haemolysed sera	0	0	50	50
	UNAV lab (4)	dilRB	CITA	Serial dilutions	0	0	61	61
SAT	UNAV lab (4)	SAT			0	0	61	61
Coombs IgG	UNAV lab (4)	Coombs			0	0	61	61
Brucellacapt	UNAV lab (5)	Brucecapt			0	0	7	7

(1) NVRI RBT positives and random sample of NVRI RBT negatives to make up total of 200 for expedition to UNAV
(2) Aliquots of sera sent from Nigeria to UNAV (number is inferior to field testing because some sera had run out)
(3) Haemolysed sera giving RBT positive result
(4) Haemolysed, weak or clear UNAV sRBT positives
(5) UNAV sRBT positives with titre of more than ½ or positives with ½ titre where cattle were found to be infected

Table 64 Serological tests selected for brucellosis screening of cattle, sheep, goats and humans in the March, June and October surveys

7.3.2 Cattle brucellosis diagnostics

7.3.2.1 Serology

7.3.2.1.1 Field screening with sRBT (FsRB)

Blood processing did not involve centrifugation. Blood was allowed to coagulate overnight in the syringes used for blood collection. The syringes were laid needle-end up, air was drawn into the top of the syringe and these were stored in a bucket indoors and in a shaded area. Serum was extracted by pipetting around the blood clot and transferred to a separate tube (Figure 84).

Figure 84 Blood processing and serum separation

Cattle sera collected on 'day 1' during the March and June surveys were screened with the standard protocol of the Rose Bengal Test (RBT) under field conditions (**FsRB**), to give following-day or 'day 2' results enabling milk samples to be collected from serological reactors the day after (day 3) (Figure 85). This strategy fitted well with the tuberculin testing regime of injecting tuberculin on day 1 and reading the test on day 3 (72 hours later) (see Chapter 11 and appendix).

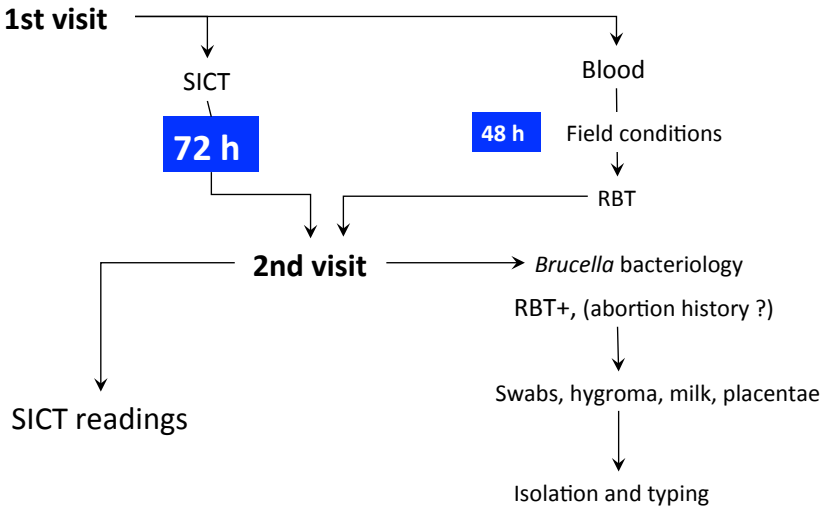


Figure 85 Parallel field BTB and brucellosis screening

The RBT was performed on flat ceramic glossy tiles using the CITA antigen and equal amounts of serum as described by Alton et al. (1988). The plates used were large rectangular plates and rocking was done manually by rotating the plate clockwise and anti-clockwise for four minutes. The RBT was performed outdoors, usually in the afternoon when the temperature was between 20-30°C and windy conditions promoted drying of the serum-antigen drop on the plate. For this reason, the antigen and serum volume were increased to 60 µl (instead of the standard 25-30 µl). RBT testing in the field was carried out by seven experienced technicians / veterinarians / researchers employed by the *Brucella* research group at the NVRI (National Veterinary Research Institute).

7.3.2.1.2 NVRI Lab re-screening of June sera with sRBT (NsRB)

Very few positives were obtained during field screening. To confirm that this finding was not due to reduced sensitivity of the sRBT under field conditions, June sera were rescreened in Nigeria under laboratory conditions. This batch of testing was undertaken on serum samples which had been stored in the NVRI freezers at -20°C (although the temperature may have risen above this sporadically due to occasional power cuts). Temperature in the laboratory ranged between 25-30°C, the same large rectangular tile was used as in the field, and rocking was also done manually.

The March sera could not be rescreened due to storage and serum quality issues.

All June sera were re-screened with the same standard protocol of the RBT as described by Alton et al. (1988), using the same CITA antigen and by the same personnel who had performed the RBT in the field. The only differences were that 25 µl of antigen + sera instead of 60 µl were used and that the test was conducted under laboratory conditions at the NVRI *Brucella* laboratory.

7.3.2.1.3 UNAV re-screening of 200 June sera with sRBT (UsRB)

Aliquots of RBT positive sera were sent to University of Navarra (UNAV) for re-screening, in addition to a random selection of negative sera to make up a total of 200 sera. The total of 2000 serum samples were not sent to Navarra at this time because of insufficient staff to aliquot the sera as NVRI was on strike during. The 200 sera were screened 'blind' by this author using the RBT under laboratory conditions. Temperature in the UNAV laboratory was 20°C, a smaller square glossy tile was used, and rocking was automated and timed (4 minutes).

7.3.2.2 Bacteriology

7.3.2.2.1 Sample collection and isolation

Bacteriology samples were collected from cattle from March and June surveys. Dr Wilson Bertu, NVRI, undertook isolation and biotyping of Brucella (Table 65).

Sampling in March was 'opportunistic', including vaginal swabs from animals that had aborted within the previous two weeks, joint aspirates of animals with hygromas, milk from lactating animals suspected of having 'bakale' (Fufulde for brucellosis) by their owners, and placentae from aborting animals (Figure 85).

In June the tuberculin testing regime of returning to the same households 72 hours after the first visit enabled sera to be screened between day 1 and day 3 visits. Milk samples were collected from lactating RBT positive animals. Vaginal swabs, placentae and hygroma aspirates were also collected as per the March survey.

All samples for *Brucella* isolation were incubated for 24 hours in peptone broth after which they were inoculated on serum dextrose agar or Trypticase soya agar (selective media) for isolation of *Brucella* organisms as described previously (Alton *et al*., 1988; de Miguel *et al*., 2011). The media plates were prepared by weighing 4g of Trypticase soy agar or dextrose agar in 100ml of sterile distilled water and

autoclaved. 2ml of *Brucella* antibiotic supplement (Oxoid) containing a cocktail of antibiotics (Polymyxin B, 2,500 IU; Bacitracin, 12,500 IU; Cycloheximide, 50.0 mg; Nalidixic acid, 2.5mg; Nystatin, 50, 000 IU; Vancomycin, 10.0 mg) was added per 100 ml of media. Five ml of newborn calf serum was also added before the media was poured into petri dishes. The set of inoculated plates were incubated at 37^0C for 3-7 days in 5-10% CO_2 atmosphere while another set without CO_2.

Phenotypic characterisation included 1) growth in presence of CO_2; 2) hydrogen sulphide production; 3) urease test; 4) agglutination with positive and negative *Brucella* sera; 5) agglutination with monospecific antisera A and M; 6) sensitivity to thionin and basic fuchsin dyes; 7) sensitivity to *Brucella* phages (Wb, Tb, Iz, R/C) (Alton et al., 1988). Isolates were also characterised genotypically using the Bruce-ladder multiplex PCR® (Lopez-Goni et al., 2008) to confirm the *Brucella* species. Genotyping at strain and subgroup level was undertaken using the AMOS-ERY PCR performed as described by (Ocampo-Sosa et al., 2005).

Milk	Vaginal swab	Hygroma	Placenta	Total
70	55	2	1	128

Table 65 Number of samples collected for *Brucella* isolation from KGR

7.3.3 Small ruminant serology

7.3.3.1 Field screening with sRBT (FsRB)

Small ruminant sera collected during the March, June and October surveys were screened with the sRBT under field conditions using the CITA antigen (Table 64). Field screening give same day results to inform the community of their small ruminant brucellosis status (Figure 86). The method was as described in 7.3.2.1.1.

7.3.3.2 UNAV re-screening with sRBT and mRBT (UsRB & UmRB)

Because of uncertainty surrounding the robustness of the RBT under field conditions, sera were sent to UNAV for re-screening under lab conditions. Due to cost constraints only sera collected during the October survey were expedited.

Sera were re-tested using sRBT (**UsRB**) and mRBT (**UmRB**) in parallel by four experienced operators (Figure 86). The method used was as described in 7.3.2.1.3.

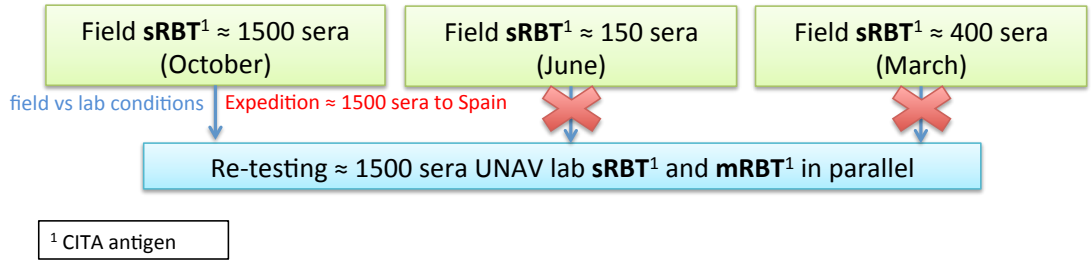


Figure 86 Serological screening and re-screening of small ruminant sera collected during March, June and October surveys

7.3.4 Human serology

7.3.4.1 Field screening with sRBT (FsRB)

Field screening was undertaken to give persons sampled same day results as part of ethical conditions for approval of the study (see appendix for ethical approval document) (FsRB). Human sera were screened using the RBT (CITA antigen) under field conditions. The test was performed as for animal brucellosis (25 + 25 µL; standard protocol). The interpretation of the agglutination was as for animal sera.

7.3.4.2 Lab re-screening with panel of serological tests

Re-screening under laboratory conditions was undertaken to rule out potential sensitivity issues related to performing the RBT under field conditions. All sera were initially screened with sRBT using the CITA antigen (**UsRB**).

Atypical clumping/agglutination reactions were observed with haemolysed sera (Figure 87). Haemolysed sera were rescreened with the supernatant of the RBT (RBT was centrifuged until all *Brucella* cells deposited and no *Brucella* antigen remained, **RBT SN**). Those still giving positive agglutination were confirmed to be unspecific reactions and those found to be RBT negative were assumed to be RBT positive.

All weak and clear sRBT positives were then screened with SAT and Coombs (IgG) tests as described by Beaton and Forsyth (1984) and RBT serum dilutions were performed to determine titres. Brucellacapt® was performed on sera with sRBT titres of ¼ or more or on sRBT positive sera (any titre) from persons whose cattle had tested sRBT positive (Figure 88). For full protocols of tests used refer to appendix.

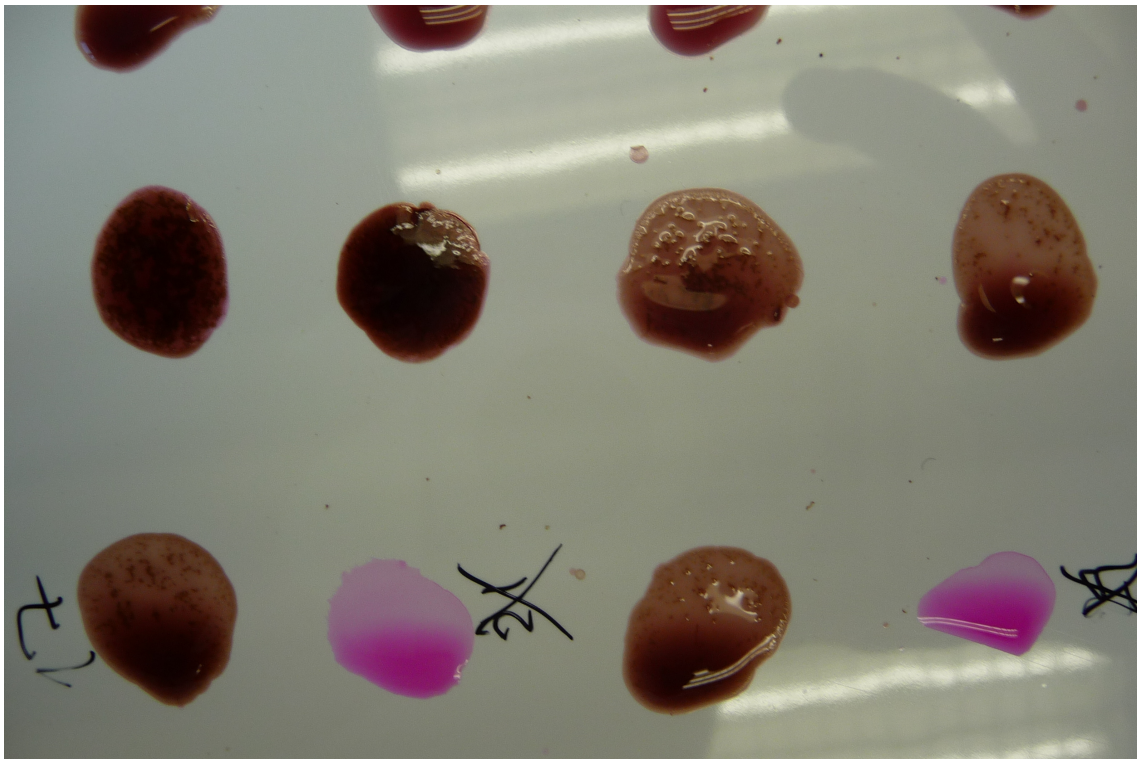


Figure 87 Appearance of sRBT agglutination reactions in haemolysed sera

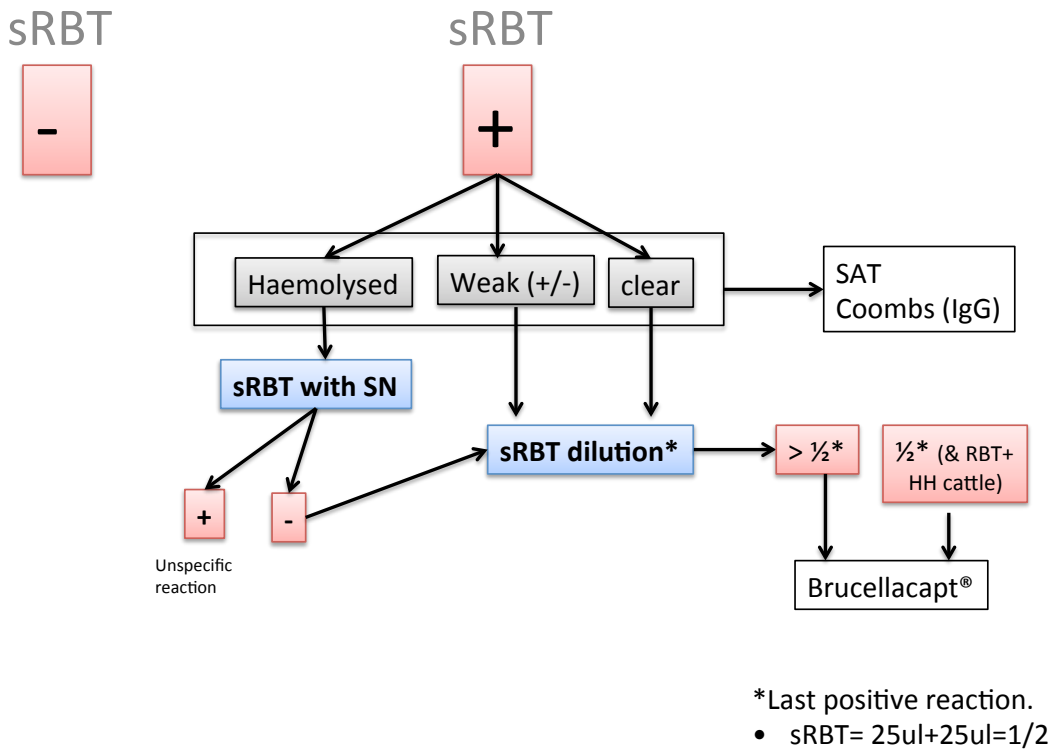


Figure 88 Use of serological tests for human sera sent to UNAV

7.4 Results

7.4.1 Cattle serology

Ten positives were detected using FsRB during the March survey. The results show that the FsRB, NsRB and UsRB detected a similar number of positives (10, 11 and 12 respectively) for June sera. Use of the test under lab conditions yielded one or two more positives than under field conditions (Table 66). Overall 18 sera (Table 67) from 10 households/herds (Table 68) gave positive results in FsRB and/or NsRB and/or UsRB. Hence whilst the overall number of positives is similar between FsRB, NsRB and UsRB the concordance between different tests for positive results is low. Indeed only three sera were found to give a positive result in all three tests.

Agreement between tests/conditions applied to the 200 cattle June survey sera sent to UNAV for rescreening is presented in Table 69 for individual sera and Table 70.

Kappa values were calculated in Winpepi© statistical software and the level of agreement (*kappa* values) is categorised according to Landis and Koch (1977) guidelines: over 0.80, very good agreement; 0.61-0.80, good; 0.41-0.60, moderate; 0.21-0.40, fair; and 0.20 or less, poor agreement. For paired observations prevalence-adjusted bias adjusted *kappa* (PABAK) are reported. PABAK is the value *kappa* would take if there were no bias and if the prevalence of each category was equal, to correct for the inequality between the prevalence of positive and negative results (many negative versus few positive results). Simulation studies, however, have suggested that PABAK may overestimate agreement. Agreement of three ratings was also computed in Winpepi©. Concordance between the three tests/conditions at individual sera and herd level was found to be fair (*kappa* = 0.40) (Table 69) and moderate (*kappa* = 0.42) (Table 70) respectively.

Test/condition	*March survey*		*June survey*		*October survey*	
	N sera	N positive	N sera	N positive	N sera	N positive
FsRB	1724	10	1972	10	0	
NsRB	0		1972	11	0	
UsRB	0		200	12	0	

Table 66 Number of cattle sera screened and number of positives detected

Cattle ID	*SN*	*FsRB*	*NsRB*	*UsRB*
2003016	1	0	+	+
2003080	2	+	+	+
2003084	3	+	+	+
2003085	4	0	+	+
2003086	5	+	+	+
2004008	6	+	0	0
2007043	7	+	+	0
2011018	8	+	0	0
3001045	9	+	0	0
3001053	10	+	0	0
3002017	11	0	0	+
3005021	12	0	0	+
4001002	13	+	0	0
4001060	14	0	0	+
5002002	15	0	0	+
6001003	16	0	0	+
6001008	17	+	+	+
6001023	18	0	0	+
Total	***18***	***10***	***11***	***12***

Table 67 Sera positive in FsRB +/- NsRB +/- UsRB

HH ID	*SN*	*FsRB*	*NsRB*	*UsRB*
2003	1	+	+	+
2004	2	+	0	0
2007	3	+	+	0
2011	4	+	0	0
3001	5	+	0	0
3002	6	0	0	+
3005	7	0	0	+
4001	8	+	0	+
5002	9	0	0	+
6001	10	+	+	+
Total	***10***	***7***	***3***	***6***

Table 68 Herds positive in FsRB +/- NsRB +/- UsRB

Tests/conditions	*Kappa*	*95% CI (based on SE) or p-value*	*Agreement*	*PABAK*	*Agreement*
FsRB & UsRB	0.33	0.06-0.59	fair (poor-moderate)	0.86	very good
FsRB & NsRB	0.45	0.17-0.72	moderate (poor-good)	0.89	very good
NsRB & UsRB	0.49	0.23-0.75	moderate (fair-good)	0.89	very good
FsRB, NsRB & UsRB	0.40	0	fair		

Table 69 Concordance of 200 June survey cattle sera sent to UNAV for rescreening

Tests/conditions	*Kappa*	*95% CI (based on SE) or p-value*	*Agreement*	*PABAK*	*Agreement*
FsRB & UsRB	0.36	-0.02-0.74	fair (poor-good)	0.65	good
FsRB & NsRB	0.55	0.18-0.92	moderate (poor-very good)	0.8	good
NsRB & UsRB	0.38	-0.04-0.81	fair (poor-very good)	0.75	good
FsRB, NsRB & UsRB	0.42	0	moderate		

Table 70 Concordance at herd-level of 200 June survey cattle sera sent to UNAV for rescreening

7.4.2 Bacteriology in cattle

Culture of the 128 samples collected in the KGR yielded three *B. abortus* isolates (Table 71). The three strains show characteristics consistent with Biovar 3, and genotyping places these strains in the biovar 3a cluster (distinct from *B. abortus* biovar 3b in Europe) (Ocampo-Sosa et al., 2005, Le Fléche et al., 2006).

Sample type	*Total (N)*	*Isolate*	*Brucella species*
Vaginal swab	70	1	*B. abortus*
Milk	55	1	*B. abortus*
Hygroma	2	1	*B. abortus*
Placenta	1	0	0
Total samples	**128**	**3**	**3**

Table 71 *Brucella abortus* isolated from various samples from KGR (Bertu et al., unpublished)

7.4.3 Small ruminant serology

The results show that very few sheep and goat seropositive sera were detected using the sRBT, both under field and UNAV lab conditions (Table 72). Rescreening with sRBT at UNAV under lab conditions picked up an additional one or two positives,

which is similar to that observed with cattle sera. Table 73 and Table 74 show that concordance between FsRB and UsRB is poor for positives both for sheep and goats.

Species	*Test/condition*	*March survey*		*June survey*		*October survey*	
		N sera	N positive	N sera	N positive	N sera	N positive
Sheep	FsRB	275	1	119	0	718	2
	UsRB	0		0		683	2
	UmRB	0		0		695	51
Goat	FsRB	79	0	0		781	0
	UsRB	0		0		761	2
	UmRB	0		0		739	16

Table 72 Number of sheep and goat sera screened and number of positives detected under different tests/conditions in the March, June and October surveys

HH ID	***FsRB***	***UsRB***
1009	-	+
	-	+
2022	+	-
4010	+	ND
Total	***2***	***2***

Table 73 Results of FsRB and UsRB positive sheep, October survey

ID Oct	**FsRB**	**UsRB**
1013	-	+
	-	+
Total	***0***	***2***

Table 74 Results of FsRB and UsRB positive goats, October survey

7.4.4 Human serology

Screening of the 1126 human sera with sRBT under field conditions yielded no positives (Table 75). Re-screening of the 976 sera sent to UNAV under lab conditions yielded 67 RBT positives, 14 of which were from normal sera and 53 of which were from haemolysed sera (Table 75).

All 67 RBT positive/suspicious sera were screened with complementary tests (SAT, Coombs IgG +/- Brucellacapt). Haemolysed sera were also screened with the supernatant of the RBT, consisting of buffer without antigen (RBT SN).

All complementary tests were found to be negative for the 14 non-haemolysed sera (Table 76). Testing of haemolysed samples with the antigen-free supernatant of the RBT confirmed 35 out of the 50 atypical reactions from haemolysed sera were false

positives due to non-specific reactions (these were also found to be positive with the buffer/supernatant of the RBT only (RBT SN) (Table 77). Results of complementary tests for the RBT positive haemolysed sera found to be RBT SN negative are shown in Table 78. These were SAT, coombs and Brucellacapt negative. The serological results of the three haemolysed samples for which there was insufficient sera to perform the RBT SN are shown in Table 79. Two out of the three sera were SAT and coombs negative. Sera ran out for one RBT positive sample from household 2018 and this sera could not be screened with adjunctive tests.

RBT result	*UsRB*			*FsRB*
	Sera status	*RBT SN*	*N*	N
Positive (weak) Positive (atypical)	Non-haemolysed Haemolysed	ND positive negative ND	14 35 15 3	
Sub-total +ve			***67***	***0***
Negative	Non-haemolysed Haemolysed	ND ND	906 3	
Sub-total -ve			***909***	***1126***
TOTAL			**976**	**1126**

Table 75 Number of UsRB and FsRB positive and negative human sera, categorised according to presence of absence of haemolysis

SN	HH ID	Serum titres/results				
		RBT	RBT SN	SAT	Coombs	Brucapt
1	1005	2±	ND	<20	<20	ND
2	1005	2±	ND	<20	<20	ND
3	1005	2±	ND	<20	<20	ND
4	1013	2±	ND	<20	<20	ND
5	2001	2±	ND	<20	<20	ND
6	2002	2±	ND	<20	<20	ND
7	2002	2±	ND	<20	<20	ND
8	2002	2±	ND	<20	<20	ND
9	2003	2±	ND	<20	<20	ND
10	2008	2±	ND	<20	<20	ND
11	2008	2±	ND	<20	<20	ND
12	3007	2±	ND	<20	<20	ND
13	3012	2±	ND	<20	<20	ND
14	3013	8±	ND	<20	<20	ND

Table 76 Results of serological tests for non-haemolysed human sera (± weak positive, ND- not done)

SN	HH ID	Serum titres/results				
		RB	RBT SN	SAT	Coombs	Brucapt
1	2011	2	+	<20	<20	ND
2	2011	2	+	<20	<20	ND
3	2011	2	+	<20	<20	ND
4	2013	2	+	<20	<20	ND
5	3002	8	+	<20	<20	ND
6	3007	2	+	<20	<20	ND
7	3008	2	+	--	--	ND
8	3008	2	+	<20	<20	ND
9	3009	2	+	<20	<20	ND
10	3009	2	+	<20	<20	ND
11	3009	2	+	<20	<20	ND
12	3009	2	+	<20	<20	ND
13	3013	2	+	<20	<20	ND
14	4004	2	+	<20	<20	ND
15	4006	2	+	<20	<20	ND
16	4008	2	+	<20	<20	ND
17	4012	2	+	<20	<20	ND
18	4012	2	+	<20	<20	ND
19	6001	2	+	<20	<20	ND
20	6001	2	+	<20	<20	ND
21	Butcher	2	+	<20	<20	ND
22	Butcher	2	+	<20	<20	ND
23	Butcher	2	+	<20	<20	ND
24	Butcher	2	+	<20	<20	ND
25	Butcher	2	+	<20	<20	ND
26	Butcher	2	+	<20	<20	ND
27	Butcher	2	+	<20	<20	ND
28	Butcher	2	+	<20	<20	ND
29	Butcher	2	+	<20	<20	ND
30	Butcher	2	+	<20	<20	ND
31	Butcher	2	+	<20	<20	ND
32	Butcher	2	+	<20	<20	ND
33	Butcher	2	+	<20	<20	ND
34	Butcher	2	+	<20	<20	ND
35	Butcher	2	+	<20	<20	ND

Table 77 Results of serological tests for haemolysed human sera positive to RBT SN

SN	HH ID	Serum titres/results				
		RBT	RBT SN	SAT	Coombs	Brucapt
1	2013	2	0	<20	<20	ND
2	3002	>16	0	<20	<20	80/160
3	3002	>16	0	<20	<20	<20
4	3007	>16	0	<20	<20	<20
5	3007	2	0	<20	<20	ND
6	3008	2	0	<20	<20	ND
7	3008	2	0	<20	<20	ND
8	3008	2	0	<20	<20	ND
9	4003	4	0	<20	<20	<20
10	4003	2	0	<20	<20	<20
11	4004	4	0	<20	<20	ND
12	6001	4	0	<20	<20	ND
13	Butcher	>16	0	<20	<20	<20
14	Butcher	>16	0	<20	<20	ND
15	Butcher	>16	0	<20	<20	<20

Table 78 Results of serological tests for haemolysed human sera negative to RBT SN

SN	HH ID	Serum titres/results				
		RBT	RBT SN	SAT	Coombs	Brucapt
1	2013	2	ND	<20	<20	ND
2	2018	2	ND	--	--	ND
3	3009	2	ND	<20	<20	ND

Table 79 Results of serological tests for haemolysed human sera with unknown RBT SN results

7.5 Discussion

7.5.1 Cattle serology

The number of sera found to be positive with FsRB (March), FsRB (June), NsRB (June) and UsRB (June) were equivalent at 10, 10, 11 and 12 respectively (Table 66). The number of sera positive in FsRB and/or NsRB and/or UsRB for June is, however, substantially higher at 18, demonstrating that concordance for positivity between these three tests is low (concordance for negativity, however, is good, see below). Indeed the overall agreement between FsRB, NsRB and UsRB as defined by kappa was found to be 0.40 and 0.42 at individual (Table 69) and herd level (Table 70) respectively for the 200 sera sent to UNAV for blind testing. The moderate concordance between tests is likely due to a combination of the following factors: 1. variations in RBT protocol and conditions; 2. quality of sera; 3. operator limitations (mislabelling and recording errors and level of training). We discuss each of these factors here below. The likelihood of having missed positives even though only 200 of the 2000 June sera were sent to UNAV for rescreening is discussed.

7.5.1.1.1 Variations in RBT protocol and conditions

The problems identified for RBT performed under field and/or laboratory conditions included: 1) separation of serum; 2) storage of antigen; 3) antigen-serum mixing time; 4) temperature; and 6) use of reference positive and negative sera.

7.5.1.1.1.1 Separation of serum

The sera separation method may not have been optimal during fieldwork. Blood samples were left to clot at room temperature overnight and serum extracted by decanting or using a pipette rather than by centrifugation. It is possible that remaining fibrin may have caused false negative results.

7.5.1.1.1.2 Storage of antigen

Another issue was the conditions of storage of the antigen for use during fieldwork. The RBT antigen was stored in a fridge turned on during 6 out of 24 hours per day. There was no mains electricity in the KGR and petrol was too expensive to switch on the generator for more than 6 hours a day. This constant cooling and heating effect over the one month spent in the field may have affected the 'quality' and performance of the antigen.

7.5.1.1.1.3 Antigen-serum mixing time

Field serology was undertaken under severe time constraints (imposed by availability of daylight in the absence of electricity). This led to many sera being tested simultaneously on the same plate (Figure 89) that promoted recording errors.

The recommendation is for a maximum of eight sera to be tested as a batch, which is what was done at UNAV. The main issue with screening more than eight sera per plate is that the antigen-serum reaction cannot be timed properly, and will be more than 4 minutes from mixing to reading for some of the samples. For example, the mixing time of the top right sample in Figure 89 is likely to be longer than for the bottom left sample for the plate with 60 samples. A large rectangular plate instead of the recommended small square plate was used in Nigeria (Figure 89, Figure 90). Plates in Nigeria were shaken by hand. Use of large rectangular plates encourages greater mixing of sera on the edge of the plate than those in the middle.

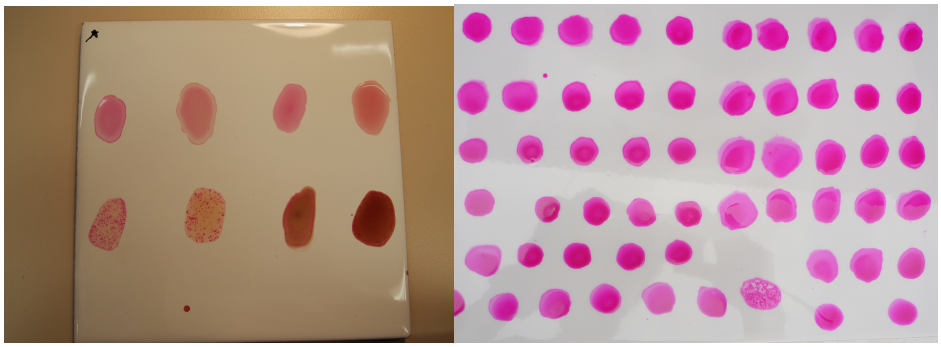


Figure 89 Doing the sRBT and mRBT in parallel on the same tile for four sera at UNAV (left) as compared to doing numerous sera on the same plate under field conditions (right)

Figure 90 Doing the RBT under field conditions

7.5.1.1.1.4 Temperature

The RBT agglutination reaction is sensitive to temperature and must be conducted at 22 ± 4 ºC. Field screening was performed outdoors (Figure 90) and frequently did not meet these conditions, which could have affected the agglutination time.

7.5.1.1.1.5 Reference positive sera

Limited supplies of reference positive sera were available in Nigeria, which meant that these were not used on every plate. Reference positive sera were used daily in the field and lab to confirm that antigen was functioning.

The blind testing experiment undertaken on the 200 June sera confirm that variations in protocol may produce differences in results. In fact when these same sera were sent to an Official Spanish Veterinary Laboratory for screening with sRBT, further discrepancies were found (Figure 94). In this case, the discrepancies are partly due to the use of a different antigen. The Granada antigen used in Official Veterinary laboratories in Spain is more sensitive but less specific than the CITA antigen, as it is optimised to suit the purpose of brucellosis surveillance and animals can be checked in a second visit. This means that the Granada antigen lacks the specificity of the CITA antigen. There are technical differences in the protocol used for RBT screening in the Spanish Offical lab as compared to that used for FsRB, NsRB and UsRB. The plates used are large and rectangular, and an automated shaker is used to mix serum-antigen drops (Figure 93). The plates had wells making it more difficult to observe

positive samples with the characteristic agglutination in the periphery of the drop (Figure 91) as compared to the classical 'clumping' (Figure 92).

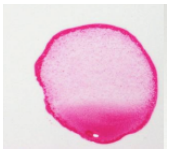


Figure 91 RBT positive serum with fine clumps and rim formation

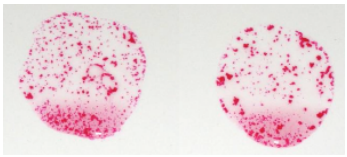


Figure 92 RBT positive serum with coarse clumping and definite clearing

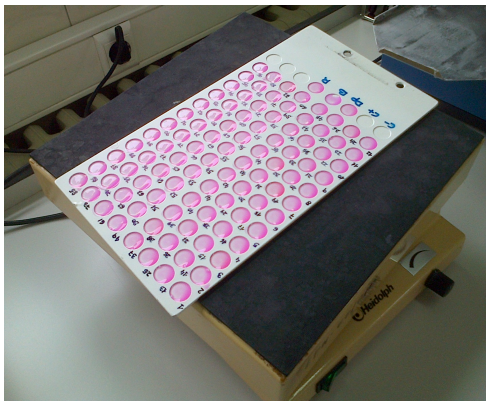


Figure 93 Use of automatic shaker to mix serum and antigen at government lab, note use of reference positive and negative sera on each plate for comparison

7.5.1.1.2 Quality of sera

The separated sera were kept in a freezer, switched on for 6 hours daily until the phase of fieldwork was over after which they were transported back to NVRI. Sera were then stored at the lab in NVRI, which despite having mains electricity often experiences power outages, sometimes for days. This thawing, refreezing cycle is likely to have had impacted on the quality of proteins, including antibodies.

7.5.1.1.3 Operator limitations

The 'human factor' may have had a big impact on discrepancies found between FsRB, NsRB and UsRB. Operators in the field and at the laboratory in NVRI had variable technical abilities and experience of performing the RBT. This may have led

to interpretation bias. The screening of samples at UNAV (Spain) was undertaken by the author of the thesis, under the supervision of Prof. Ignacio Moriyon and Dr Diaz. The screening of large numbers of samples on the same plate in Nigeria may have also lead to recording errors with regards to positive samples. Another potential source of recording/labelling errors during field screening was operator fatigue. The daily screening of samples was undertaken after a long morning of tiring fieldwork. Labelling errors associated with aliquoting of sera for the purpose of shipment to UNAV may also account for some of the discrepancies.

7.5.1.2 How can we be sure we did not miss positives?

The results shown in Table 67 show that six out the 18 sera found to be positive in any test (FsRB, NsRB and UsRB) were only found to be positive in UsRB. It is logical to surmise that since these six positives were not detected in Nigeria, that other sera interpreted as negative in Nigeria could in fact have been positive. How can we be sure that positives were not missed from the total batch of 2000 June sera?

The sera sent to UNAV consisted not only of sera that had tested positive in the NsRB but also those positive in the modified RBT (NmRB) (Figure 94). The modified protocol of the RBT has not been validated for use in cattle sera and is predicted to be oversensitive to the detriment specificity, hence the reason the results of this test have been excluded from the analysis. The use of the 'oversensitive' NmRB, however, ensured that all suspicious and potentially positive sera were sent to UNAV for rescreening. In fact only eight sera out of the 142 sera interpreted as negative by NVRI and sent to UNAV for rescreening (5.6%) were found to give positive results in Spain (Table 80). Those eight 'positives' only gave weak positive results or were found to be positive in the 'oversensitive' mRBT and GsRB (Spanish Government Lab sRBT test), and are in most likelihood false positives (Table 81). 94% of sera found to be negative in the NmRB were also found to be negative by all other labs/tests. This suggests that it is very unlikely that there were potential positives in the 1800 sera not sent to UNAV.

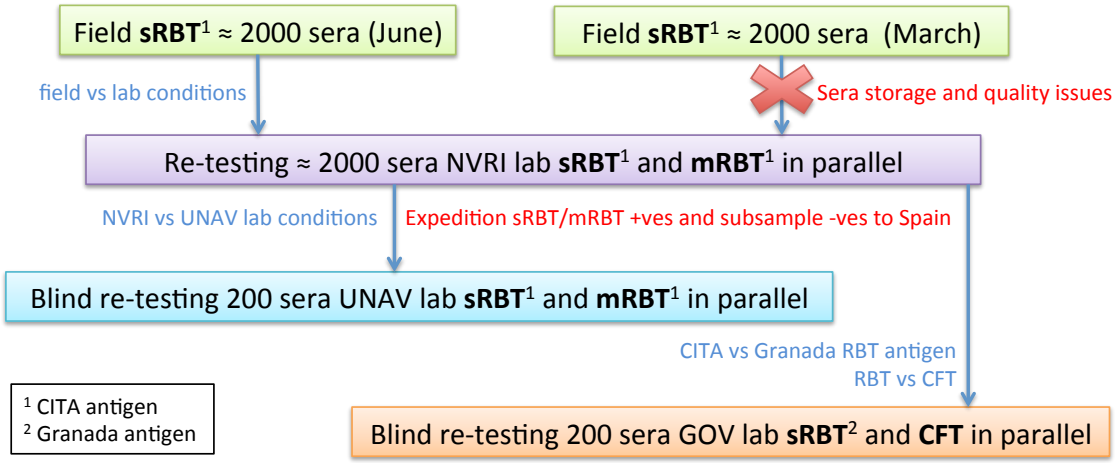


Figure 94 Serological screening and re-screening of cattle sera collected during March and June surveys

Serology results	*N*	*%*
Neg NmRB, NsRB. FsRB, UsRB, UmRB, GsRB	134	94.4
Neg NmRB, Pos FsRB +/- UsRB, +/- UmRB, +/- GsRB	8	5.6
Total	142	100.0

Table 80 Serological results of cattle sera found to be NmRB negative

SN	*HH ID*	*Serology results*					
		FsRB	NsRB	NmRB	UsRB	UmRB	GsRB
1	1002	0	0	0	0	+/-	0
2	1004	0	0	0	0	+	0
3	2011	+	0	0	0	0	0
4	3005	0	0	0	+/-	+	+
5	3005	0	0	0	0	+/-	+/-
6	3006	0	0	0	0	+/-	0
7	3006	0	0	0	0	+/-	0
8	4001	0	0	0	0	+/-	+

Table 81 Results of eight cattle sera found to be NmRB negative and positive in other tests

7.5.1.3 Recommendations

The sRBT performed under field conditions picked up five out of 18 sRBT positives detected under lab conditions, and demonstrates the robustness of this test under sub-optimal resource-poor country field conditions. The value of the FsRB to provide same day results, making it a pen-side diagnostic, should not be under-estimated in the context of marginalised communities. Modification of the protocol used in Nigeria under field conditions would likely improve the performance of RBT, including: i) use of a mechanical centrifuge; ii) use of smaller square plates; iii)

screening of 8 sera maximum on one plate; iv) use of reference positive sera on each plate; v) timing of reaction/mixing time; vi) training of operators.

Field conditions such as ambient temperature and storage of antigen are challenging to improve. Rescreening under lab conditions is advisable to increase the reliability. The disadvantage of this approach is that rescreening takes time and doubles the cost of labour and antigen (antigen cost per sample, however, is very low).

Awareness of the limitations of each test and the conditions under which it was undertaken is very important for correct interpretation of results. For the purpose of prevalence estimates, infected animals are to be defined as those positive to FsRB and/or UsRB and/or NsRB positive because all used the same standardised antigen validated against panels of gold standard reference positive and negative sera. All other samples are interpreted as negative as there is not enough evidence on the performance of mRBT in cattle and the GsRB used an oversensitive antigen.

The performance of serological tests for brucellosis diagnosis needs to be assessed for the Nigerian extensive livestock production system. Currently almost nothing is known about potential breed or physiological differences. Local cattle are severely under-nourished and parasitized and may be so hypoproteinaemic that they may not be able to synthesise immunoglobulins to the same extent as European cattle. Infected animals are likely to have been infected for a long time, and we do not know if the antibody levels decrease overtime with long-time evolution of disease. Studies from Europe deal with short duration profiling of infection as infected animals were culled and even experimental animals were not kept alive for 10 years, whereas animals in the KGR context live to an old age (especially breeding females). Animals with long-standing infections may recover and no longer show an antibody response.

The results of this study have shown that even the simplest tests require some training and standardisation (refer to 7.2.3). Any brucellosis test, including the RBT, has to be adjusted for its specific context and purpose. The purpose of RBT used for an epidemiological survey in Nigeria is not the same as for surveillance purposes in Europe. Context-specific protocols, conditions and cut-offs need to be validated for all serological tests and antigens. The only way this can be achieved is through the building up of panels of reference positive and reference negative sera specific to the

context in which the test will be used. Reference positive sera are those obtained from cattle from which *Brucella* has been isolated. Bacteriology, therefore, is a vital component of solving the puzzle of brucellosis diagnostics in Nigeria and should be undertaken in parallel to serological investigations.

7.5.2 Bacteriology in cattle

The low number of isolates relates to the protocols used for bacteriology in Nigeria. Problems include culturing of samples in TSB overnight before plating on selective medium (Farrell's). The method can enrich brucellae when the sample only contains the pathogen (for example, blood or hygroma fluids taken aseptically) but in most cases TSB effectively 'enriches' the samples for contaminants. Indeed, the use of good selective media appears to have limited the contaminants. Taking into account the low individual prevalence, the number of isolates obtained is commendable.

Brucella was isolated from a hygroma sample collected during the March survey and one vaginal swab and milk sample collected during the June survey. This shows that it is important to collect a wide variety of samples. Hygroma samples are easy to collect and experience in Nigeria (Bertu et al., unpublished) would suggest that the high bacterial load makes it an optimal sample for culture. Collecting vaginal swabs from aborting animals and milk from RBT positive animals is also a good strategy. The low number of isolates can be due to a detrimental effect of the TSB enrichment, or because the selective medium available commercially (Farrell's medium) is inhibitory for some *Brucella* strains (de Miguel et al., 2011). Bacteriology remains the unequivocal test to confirm presence of *Brucella* due to its 100% specificity.

The bacteriological/molecular characterisation demonstrates that *B. abortus* biovar 3a- rarely present in developed countries and of largely unknown zoonotic potential- is circulating in cattle of the KGR. Preliminary evidence suggests that *B. abortus* biovar 3a is dominant or restricted to Africa but little is known about its virulence and other biological properties. Isolation of *B. abortus* biovar 3 from cattle, human and dromedary samples from Africa has been accomplished (Sanogo et al., 2013a, Bankole et al., 2010, Verger and Grayon, 1984, Le Fleche et al., 2006, Dean et al., 2014, Muendo et al., 2012). A recent bacteriological study in Nigeria yielded 25 isolates mainly from cattle and from sheep and horses, all of which were reported to

be *B. abortus* biovar 1 (Ocholi et al., 2004b). Re-examination of 20 of these isolates however, shows characteristics consistent with *B. abortus* biovar 3, and VNTR genotyping (Le Fleche et al., 2006) places these strains in the biovar 3a cluster (Ducrotoy, Bertu, Moriyón, and Ocholi, unpublished).

7.5.3 Small ruminants

Few FsRB and UsRB positives were obtained for small ruminants. Reasons for discrepancies between FsRB and UsRB results are as that discussed above for cattle.

Despite having few sRBT positives, many mRBT positives were detected. A study by Blasco et al. (1994b) demonstrates that mRBT in small ruminants is more sensitive than sRBT (by 10% approx.). Our results, however, show too much of a discrepancy between the number of sRBT positives and mRBT positives, suggesting that the additional positives are not due to the increased sensitivity of mRBT (as it should only have yielded 10% more positives). Hence it is more likely that mRBT positives, which were found to be negative to sRBT, are false positives. The mRBT, as for cattle, may be picking up low titre antibodies in 'contact' animals. The Blasco et al. (1994b) study was based on *B. melitensis* infected sheep. There is evidence to suggest that small ruminants kept with infected cattle can become infected with *B. abortus* (Ocholi et al., 2005). Bacteriology was not undertaken in small ruminants in this survey. The pattern of high seropositivity in cattle versus negligible seropositivity in small ruminants would suggest that *B. abortus* may be circulating and that due to the close contact between cattle and sheep and to a lesser extent goats, spillover may occur. Currently nothing is known about the performance of serological tests in *B. abortus* infected sheep and this needs to be studied carefully.

The results demonstrate that both sRBT and mRBT in small ruminants need to be re-validated for this context. Presently, the presumption is that sheep and goats sera found to be positive in the mRBT only are unlikely to be infected but there is too much uncertainty surrounding RBT results under KGR conditions.

7.5.4 Humans

The human serology strongly suggests that there is no human brucellosis in the KGR. Even though positives were obtained in the UsRB, those were either weak positives

of low titre (titre of 2 for all except one) or from haemolysed sera. These positives subsequently gave negative results in the SAT, Coombs and Brucellacapt. This finding and the fact that none of the sera gave positive results during field screening with RBT suggests that suboptimal storage conditions in Nigeria may have affected the quality of sera subsequently sent to UNAV for rescreening.

7.5.4.1 Weak UsRB positives

There were 14 weak UsRB samples. The sRBT has a sensitivity of over 99% in humans, and hence false negative results are unlikely. In non-endemic areas, false positive results are also unlikely (specificity is over 99% when *Y. enterocolitica* O:9 is absent). In endemic areas, however, (weak) positive results can result from contact with the pathogen in the absence of infection, and one study has estimated the DSp as approximately 92% (Ruiz-Mesa et al., 2005). Díaz et al. (2011) modified the RBT to test serum dilutions and observed that RBT titres below the 8 threshhold are likely to correspond to professionals that have contacts with infected animals and not true brucellosis cases. In our study, 13 of those 14 sera gave RBT titres of 2. This and the fact that all of these sera were negative the SAT and Coombs test makes it highly unlikely that the sera belonged to *Brucella*-infected individuals. Similarly, the one serum with a titre of 8 is also unlikely to be of an infected person as it also gave negative SAT and Coombs results. This is an intriguing result because *B. abortus* is present in the KGR cattle herds and the pastoralists do not take special precautions to avoid milk-borne infections (see Chapter 9).

7.5.4.2 Haemolysed sera

Of the 56 haemolysed sera sent to UNAV and rescreened, only 3 did not give atypical/strange clumping reactions (Figure 87 and Table 75). Subsequent testing of these suspicious positives with an antigen-free supernatant of the RBT (RBT SN) confirmed that agglutinations were still visible in 35 samples. This left 15 RBT SN negative samples of which 9 gave RBT titres of 4 or more. The fact that all high RBT titres were detected in haemolysed sera, and that these sera gave negative results in the SAT, Coombs and Brucellacapt strongly suggests that they are not positive.

The reason for non-specific reactions obtained with haemolysed sera is unclear. These atypical reactions were not observed during field screening. It is possible that storage conditions of these sera affected their quality. As has been previously described, sera were stored in Nigeria for many months prior to being sent to UNAV and were subjected to thawing and re-freezing cycles.

Non-specific reactions observed in haemolysed sera may have been due to the presence of haemoglobin or other red cell components. Haemolysed samples were common in the KGR context because of various factors: i) co-existing haemolytic anaemia (or sickle cell anaemia); ii) poor venepuncture technique and haemolysis of sample; iii) co-existing haemolytic infectious disease (e.g. malaria). The main conclusion is that these atypical clumping reactions are false negative results.

Haemolysed sera giving atypical/clumping RBT reactions were present in 19% (14 out of 75) of the households. 71% (10 out of 14) of affected households had more than one individual with a haemolysed sample (Figure 95). This clustering at household level may suggest that genetics/health status is playing a role. The butcher cohort had the largest proportion of haemolysed sera (33% of the 52 haemolysed samples). Over-representation of this group may be related to the fact that they were blood sampled on the same day by the same operator. Haemolysis may a result of poor blood sampling technique. Butchers are from another ethnic group- they are Hausa rather than Fulani- and genetics or health status could play a role.

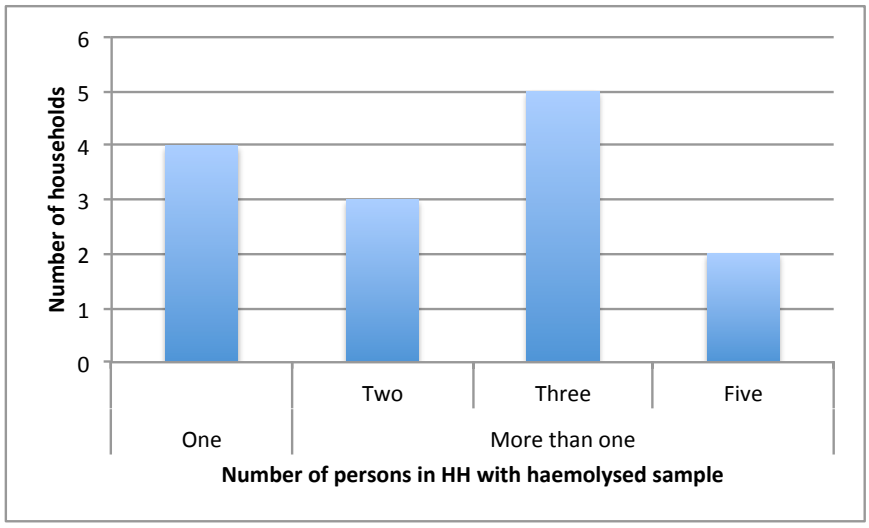


Figure 95 Number of persons in household with haemolysed sample

7.5.4.3 Importance of anamnesis and bacteriology

There are persons that develop antibodies upon contact with the bacterium but do not become infected. Indirect evidence suggests that infection is more easily acquired from sheep or goats (*B. melitensis*) than from cattle (*B. abortus*). Cattle in KGR have been identified as infected with *B. abortus* biovar 3a. Infection of individuals cannot be based only on serology, anamnesis and clinical examination by a medical doctor are needed to make a definitive diagnosis.

7.6 Conclusion

The application of RBT for identification of brucellosis in KGR has raised issues as to performance and robustness of serological tests in pastoralist settings. RBT was robust even under sub-optimal conditions but must be used in the right way. RBT sensitivity could be improved but should be balanced against specificity. Variations from standard protocol affected RBT performance. All of the conditions specified by the standard protocol could not be met under field conditions and sera should be re-screened under laboratory conditions. Furthermore, the simplicity of the RBT can lead to injudicious use, users must be aware of the importance of using good quality, standardised antigen. Applying positive and negative reference sera on the same plate as the serum under test is essential for reliable interpretation of agglutination. The limited availability of reference positive sera in Nigeria should be addressed since these labs as situated within easy reach of infected herds.

The limitations of the RBT test descrived apply to all S-LPS tests including immunosorbent assays. The way forward would be parallel applications of RBT in resource poor settings, together with bacteriology (as the gold standard is needed) backed up by clinincal observation.

8 Chapter 8 Brucellosis prevalence in KGR

8.1 Introduction

This chapter examines prevalence and risk factors for brucellosis in the pastoralist setting of the Kachia Grazing Reserve, looking at brucellosis in multiple hosts by determining prevalence in different species. This parallel investigation of human and animal burden of disease (the application of a One Health approach) is novel in the Fulani context. Most brucellosis surveys have been conducted independently for humans and animals with human studies being almost exclusively of hospital-based surveys or sampling of at-risk professionals such as butchers and abattoir workers (see Chapter 6). The objective was to fill in some of the gaps in the evidence with regards to animal and human brucellosis in an extensive livestock production setting.

The epidemiological survey was concerned with Fulani pastoralist communities in the KGR. Pastoralist communities within this reserve practise long-range seasonal transhumance (see Chapter 5). The KGR community is heterogeneous for wealth, socioeconomic status and livestock ownership. The demography is highly dynamic, with mass influxes of new immigrants into KGR during periods of civil unrest (see Chapters 3, 4 and 5). This chapter considers the scale of the problem of brucellosis infection in the KGR. The disease burden is compared across the different species in an attempt to define the role of the different hosts both in disease transmission and as reservoirs of disease. Data for cattle, sheep, goats and humans were obtained from three cross-sectional surveys conducted in March, June and October 2011. A direct comparison of disease prevalence across the surveys undertaken is complicated by the different diagnostic practices applied in each survey.

Seropositive herds were ‘profiled’ to investigate patterns with regards to ‘type’ (age, sex, etc.) of positive animals and individuals. Risk factor analysis for positive status, both at animal or human and household level was applied to provide quantitative insights as to determinants of disease, e.g., why the disease may be more or less prevalent under certain conditions.

The issue of test sensitivity and specificity and the impact on cattle individual and herd prevalence is considered. The relationship between test validity (sensitivity and

specificity) at individual herd level is discussed. The predictive value of tests given varying true prevalence in a population is explored.

8.2 Materials and methods

8.2.1 Sampling

Blood was drawn from cattle, sheep, goats and humans for brucellosis serological testing during three cross-sectional surveys conducted in March, June and October 2011 (see Chapter 2) (Table 82).

March 2011 - The survey undertaken in March coincided with the middle/end of the dry season. At this time many households had left KGR on dry season transhumance, leaving only the sedentary households and households that had sent only part of their herd on migration. Cattle, sheep and goats from 63 randomly selected households within the KGR were sampled. Forty of the 63 randomly selected households had sheep, and 9 of the 63 had goats. Individual animal data consisting of age, sex, 'life-stage' and parity (for females) was collected from animals sampled. Questionnaires were administered to capture household-level data for risk-factor analysis. Serum samples from all species were screened in situ under field conditions using the standard protocol for the Rose Bengal Test (FsRB).

June 2011 - The survey was undertaken at the onset of the wet season shortly after a mass-immigration event. The influx of migrants into the KGR was caused by the post-election violence of April-May 2011 and displacement of numerous Fulani (see Chapter 3). All households return to KGR at the onset of the wet season, which meant the sampling frame for the June survey included households that undertake full-herd transhumance as well as the semi-transhumant and sedentary population. The June 2011 survey included sampling blood from cattle and sheep in 40 randomly selected households. Twelve of the 40 randomly selected households owned sheep.

October 2011 - The survey coincided with the end of wet season/beginning of the dry season, when KGR residents return their KGR homestead (even if they have taken their cattle on migration during the wet season). This enabled tracing of all households sampled in June to screen humans and small ruminants for brucellosis.

An additional 40 households were randomly selected to increase the human and small ruminant sample size.

The survey undertaken in October comprised blood sampling for brucellosis serology of small ruminants (sheep and goats) and humans in the same 40 households as those sampled in June, and an additional 40 households (80 households in total). Five of 80 randomly selected households refused to participate in human sampling. Butchers, considered to represent a high-risk group, were sampled.

Fifty-one households had sheep and 51 had goats, although not necessarily the same households (some had sheep only, some goats only and some both).

Individual-animal data on age and sex were collected for all small ruminants sampled. Data on age, sex, occupation and presence or absence of exposure to risk factors (e.g. consumption of raw milk) were collected for each person sampled. Household data were also collected.

Species	*No. individuals (No. HH)*			
	March	*June*	*October*	*Overall*
Cattle	1724 (63)	1972 (40)	0	3696 (103)
Sheep	275 (26)	119 (12)[1]	718 (51)[1]	1112 (77)[1]
Goats	79 (9)	0	779 (51)	858 (60)
Humans	0	0	1126 (75 & butchers)[2]	1126 (75 & butchers)[2]

Table 82 Number of animals, persons and households sampled for the March, June and October surveys
([1] 12 households sampled in June were re-sampled in October and are included in 51 total, [2] 75 households were sampled as well as all butchers of the KGR as a separate group)

8.2.2 Estimation of brucellosis prevalence

Disease occurrence is reported as prevalence for individual and herd, for each species. Prevalence estimates and confidence intervals have been calculated for herd and individual observations. The sampling strategy was based on cluster sampling methodology (see Chapter 2). In all studies, the cluster was defined as the household. The cluster size and the number found to be positive for brucellosis (according to specific interpretation criteria, see below) were entered in the WinPepi© software and estimates of prevalence of a disease were derived from observations in a cluster sample with differently sized clusters.

Prevalence was calculated as the ratio of the total number interpreted as positive to the combined number in the clusters (Abramson, 2013b). Using Cochran's procedure (Cochran, 1977), the variance of the prevalence was computed by Equation 1, where n is the number of households (HH), m_i the total number of individuals in ith HH, a_i number of infected individuals in ith HH, and p=number of HH sampled/sum of individuals sampled across all HH.

$$v(p) = \frac{1-f}{n\bar{m}^2} \frac{\sum a_i^2 - 2p \sum a_i m_i + p^2 \sum m_i^2}{n-1}$$

Equation 1 Estimation of variance of prevalence for differently sized clusters

A finite population correction ($1 - f$; where f is the sampling fraction) was applied to samples that included more than 5% of the population (Cochran, 1977, Abramson, 2013b). These samples are highlighted in Table 83. The 95% confidence limits were computed as: $p \pm t(SE)$

where p = prevalence
t = the two-tailed critical value of Student's *t* at alpha = 0.05, with (C-1) degrees of freedom.
C = number of clusters
SE = standard error

N & % of population sampled	March survey		June survey		October Suvey		Population (2010 census)		Population (2011 census)	
	Ind	HH	Ind	HH	Ind	HH	Ind	HH	Ind	HH
Brucellosis										
Cattle N	1724	63	1972	40	0	0	23327	581	41234	777
Cattle (% of pop)	7.4	10.8	4.8	5.1	0.0	0.0				
Sheep N	275	26	119	12	718	51	5914	452	10161	491
Sheep (% pop)	4.6	5.8	1.2	2.4	7.1	10.4				
Goats N	79	9	0	0	779	51	5058	386	4828	431
Goats (% pop)	1.6	2.3	0.0	0.0	16.1	11.8				
Humans N	0	0	0	0	1126	75	5252	581	9118	777
Humans (% pop)	0.0	0.0	0.0	0.0	12.3	9.7				

Table 83 Number and percentage of individuals sampled in the March, June and October surveys as compared to size of the overall population
(March survey percentages calculated based on 2010 census population, June and October surveys calculated based on 2011 census population)

Design effect (D) and rate of homogeneity (ROH) were calculated in WinPepi©. The design effect is the increase in the standard error (SE) resulting from cluster instead of simple random sampling, and provides an indication of the loss of precision due to the use of a cluster sample (Equation 2).

$D = SE^2_{\text{cluster sample}} / SE^2_{\text{simple random sample}}$

Equation 2 Formula for calculation of design effect

The variance for a simple random sample of the same size as that of the cluster sample, was calculated based on equation where N = size of population T; p = proportion with the attribute under study; and n = size of sample (Cochran, 1977).

$[(N - n) / N] [p(1 - p) / (n - 1)]$ if N was entered, or
$p (1 - p) / (n - 1)$ if N was not entered (i.e., the population size was theoretically infinite).

Equation 3 Formula for calculation of variance for a simple random sample

D is related to the average cluster size and the rate of homogeneity (ROH) (Otte and Gumm, 1997) (Equation 4).

ROH = (D-1)/(n-1)

Equation 4 Formula for calculation of rate of homogeneity (DE: design effect; n: sample cluster size)

The ROH (also known as the intra-cluster correlation coefficient) is a measure of homogeneity of responses within a cluster (Kish, 1965, Bennett et al., 1991b). The ROH for each prevalence was computed in WinPepi© from the one-way ANOVA components MSB and MSW (the between-cluster and within-cluster mean squares) by the formula in Equation 5 (Ridout et al., 1999) M is an adjusted mean cluster size, computed for this purpose by the formula for n0 (see Equation 6).

(MSB-MSW) / [MSB + MSW*(M-1)]

Equation 5 Formula for calculation of estimator of intraclass correlation

$$n_0 = \frac{1}{(k-1)}\left[N - \sum_{i=1}^{k}\frac{n_i^2}{N}\right] \quad \text{with } N = \sum_{i=1}^{k} n_i.$$

Equation 6 Formula for calculation the adjusted mean cluster size

ROH can range up to 1. For some surveys in specific species, many of the clusters contained a single positive observation, and the rate of homogeneity was found to be negative and the design effect less than 1 (Abramson, 2013b). Since brucellosis did not achieve high within-herd level prevalence, the ROH is low (<0.05 in most cases). 95% confidence intervals for individual prevalence as a simple proportion (binomial confidence interval) were also calculated in WinPepi©. The numerator (number of individuals found to be positive according to specific interpretation criteria) and denominator (number of individuals) were entered and the exact Fisher's 95% confidence interval computed.

Herd prevalence and 95% Fisher's confidence interval were also computed in WinPepi©. The exact Fisher's confidence intervals are computed by a procedure from XLIM (version SP2.5) by Simons (Abramson, 2013b).

The observations are based on a sample of a population of known size (KGR population census in 2010 and 2011). The population size of each species was entered for sampling fractions of more than 5% (Cochran, 1977), for a finite population correction to be applied. This reduces the variance and hence makes confidence intervals narrower. However, for our data, the correction had little effect as the sampling fractions were small at between 5-10% (Table 83).

8.2.3 Analysis of risk factors

8.2.3.1 Comparison of proportions (two categories)

Risk factors for presence of disease were evaluated at individual animal/person level and herd/HH levels. Different variables were examined across the different surveys and species to ask 'do proportions in two or more groups differ from each other?'. The diagnostic test result(s) were the response variables for brucellosis in this study. Comparison of proportions of 'positivity' across variables was firstly undertaken by calculating 95% confidence intervals using Fisher's exact method. Overlap of confidence intervals essentially means that no conclusion can be drawn with regards to difference in infection rate between the different categories. When interpreted with regard to the subjective theory of probability, confidence intervals provide information about the probability of the sign of an effect. If null falls outside the 95%

confidence interval, one knows the sign of the most likely (95% confidence) population parameters. If null falls within the 95% confidence interval, nothing can be said about an effect with any great degree of certainty. The effect can be positive, negative and theoretically, null (the latter is extremely unlikely. It can also be assumed that the effect might be very small (close to zero) (Brandstätter, 1999).

Proportions were compared in WinPepi© through calculation of exact probabilities (Fisher's), Pearson chi-square test and Fisher's odds ratio (with Fisher's exact CI).

8.2.3.1.1 Odds ratio

Odds ratios and exact Fisher's 95% confidence intervals for each contingency table were computed in WinPepi©. The computation of exact confidence intervals for the odds ratios used the network algorithm of Mehta et al. (1985) (Abramson, 2013a).

8.2.3.1.2 Pearson's chi-square test

A simple Pearson's chi-square test was performed in WinPepi©. The simple chi-square test was supplemented by tests with Upton's corrections in WinPepi©.

The chi-square test may be misleading if the expected frequencies (under the null hypothesis) are less than 5. In this case the Upton's adjusted chi-square is reported, which is appropriate if there is no expected value below 1 (Campbell, 2007). Upton's chi-square (Upton, 1982, D'Agostino, 1990) is the Pearson chi-square multiplied by (N - 1) / N, where N = sample size.

Values for the Fisher's exact test are also reported to compare proportions of individuals infected when sample size is <20 and there is one or more cell frequency of <1 (Campbell, 2007) (see 8.2.3.1.3 below).

8.2.3.1.3 Fisher's one-tailed test

Fisher's one-tailed test was computed in WinPepi© based on conditional probabilities, under the null hypothesis (given marginal frequencies) of each possible number in a specific cell (Abramson, 2013a). Formulae provided by Zar (1998).

8.2.3.2 Comparison of categorical data

Presence and absence of infection (according to specified interpretation criteria) was compared with respect to nominal (e.g. block, year HH moved to KGR) and ordinal (e.g. age of individual sampled) variables that had three or more categories. The year a household moved to KGR falls into a natural order and could therefore have been considered as an ordinal variable, however, for the analysis only three nominal categories were defined, including HH that had moved before 2000 (old settlers), HH that moved between 2000 and 2010 and HH that moved in 2011 (new immigrants).

WinPepi© was used to compute Pearson's chi-square test of association, odds ratio (with pairwise comparisons of all categories) and Fishers probabilities (two-tailed) for nominal data.

8.2.3.3 Testing for difference between groups

Analysis of variance was used to assess whether there was a difference in continuous variables between positive and negative individuals/ herds/ flocks/ HH. The Kruskal-Wallis one-way ANOVA was used because within-group deviations (residuals) of data did not follow a Normal distribution, and the largest within-group variance was more than twice as big as the smallest for all data (Kruskal and Wallis, 1952).

8.2.1 Prevalence and imperfect tests

8.2.1.1 Calculating true prevalence

The serological tests used for screening of samples are imperfect tests in that they have diagnostic sensitivity and/or specificity of less than 100%, thereby generating false negative and false positive results respectively (Thrusfield, 2007). Estimates of true prevalence and 95% confidence limits were calculated from the apparent prevalence as defined by the number of test positives using the online resource EPI TOOLS (http://epitools.ausvet.com.au/content.php?page=home), as described by Rogan and Gladen (1978). Blaker's confidence limits are calculated as described by Reiczigel, Földi and Ózsvári (2010). Input parameters included test prevalence or apparent prevalence, sensitivity of test, specificity of test and sample size.

8.2.1.2 Predictive value and likelihood ratios of tests

Sensitivity and specificity are measures of test validity. They are innate characteristics of a test for a given reference population and are relative stable (i.e they are rarely affected by prevalence) (Thrusfield, 2007). To interpret test results obtained for each species and test, predictive values (Positive (PPV) and Negative (NPV)) have been calculated. PPV and NPV express the probability that a given test result reflects the true status of disease, i.e. the probability that an individual or animal positive according to a test is actually positive or alternatively that a test negative individual or animal is a true negative (Thrusfield, 2007).

Likelihood ratios have also been calculated to compare the proportion of animals with and without disease, in relation to their test results. The likelihood ratio of a positive test result (LR+) is the ratio of the likelihood of a positive test in an animal that truly has the disease to the likelihood of a positive test in animal that does not have the disease (i.e. how much more likely is the test to give a true positive than a false positive), and should ideally be greater than 1 (Equation 7). The likelihood ratio of a negative test (LR-) is the ratio of the likelihood of a negative test in an animal that truly has the disease to the likelihood of a negative test in animal that does not have the disease (i.e. how much less likely is a test to give a false negative than a true negative), and should ideally be less than 1 (Equation 8) (Thrusfield, 2007).

LR+ = Sensitivity/(1-Specificity)

Equation 7 Likelihood ratio of a positive test result

LR- = (1-Sensitivity)/Specificity

Equation 8 Likelihood ratio of a negative test result

PPV, NPV, LR+ and LR- have been calculated using the online resource EPI TOOLS (http://epitools.ausvet.com.au/content.php?page=home).

8.2.1.3 Aggregate sensitivity and specificity

For very large herds or herds composed of multiple sub-herds a sample of cattle at herd level were screened. In situations where only a sample of cattle was tested in each aggregate (herd), sensitivity and specificity at the aggregate level is affected by

the sensitivity and specificity of tests used at the individual level and the sample size (i.e. number of animals sampled per herd) (Thrusfield, 2007). Equation 9 was used to calculate aggregate sensitivity and specificity can only be applied when the sampling fraction in each aggregate is less than approximately 5% (Thrusfield, 2007). The sampling fraction was calculated for all herds identified as having one or more FsRB positive during March and June surveys and was found to be over 5% for all herds (Table 84).

$Se_{agg}=1 - (1-P^T)^n$
$P^T = [P \text{ x sensitivity}] + [(1-P) \text{ x } (1 - \text{specificity})]$
$Sp_{agg} = (\text{specificity})^n$

Equation 9 Aggregate sensitivity and specificity

Where:
P^T = test prevalence
n = number of animals sampled

Survey	*Herd ID*	*Sample size (y)*	*Herd size (z)*	*Sampling fraction (y/z*100) (%)*
March	1006	16	180	8.9
	1007	100	250	40.0
	2028	32	150	21.3
June	2003	87	220	39.5
	2004	34	50	68.0
	2007	56	58	96.6
	2011	25	25	100.0
	3001	82	93	88.2
	4001	81	1500	5.4
	6001	57	170	33.5

Table 84 Sampling fraction for herds found to have one or more FsRB positive during the March and June survey

The brucellosis results for the cattle March and June survey for all herds found to have one or more FsRB seropositive were analysed in the Survey Toolbox® FreeCal Program as per methods described by Cameron and Baldock (1998) and Cameron (1999) to calculate estimates of aggregate sensitivity and specificity and the probability that herds categorised as 'positive' may in fact be *Brucella* free.

Inputs into the software included:

- Size of the population sampled (herd size);
- Sample size tested (number of cattle tested per herd);

- Number tested positive (number of FsRB positives);
- Test (sRBT) sensitivity and specificity;
- Design prevalence (the hypothetical prevalence to be detected, which was assumed to be the same as the individual prevalence detected as per each survey).

The results for each herd were displayed as follows:

- The probability (p_1) of observing this many reactors or fewer, if the herd was diseased at a level equal to or greater than the specified design prevalence (if this probability is small, we can conclude that it is very unlikely that the population is diseased; if the probability is large, then there is not enough evidence to conclude that the population is free from disease). P_1 is equivalent to the aggregate sensitivity (probability that the herd is diseased);
- The probability of missing disease (1- p_1);
- The probability (p_0) of observing this many positives or more if the population was truly disease free, i.e. the probability of incorrectly classifying a healthy population as being diseased (if this is small, then it is very unlikely that the population is free from disease; if it is large, then it is consistent with there being no disease in the population);
- The probability of correctly classifying a healthy population being healthy (1- p_0), that is, the aggregate specificity.

8.3 Brucellosis results

8.3.1 Cattle

Prevalence of bovine brucellosis for March and June surveys is shown in Table 85.

Interpretation	*N cattle (+ve)*	*Ind prev*	*95% CI (cluster)*[1]	*DE (ROH)*[2]	*95% CI (proportion)*[3]	*N herds (+ve)*	*Herd prev*	*95% CI (proportion)*[3]
MARCH	**(mean cluster size = 27.4)**							
FsRB +ve	1724 (10)	0.6	(0-1.3) (0-1.1)[4]	3.5 (0.05)	(0.28-1.06) (0.29-1.05)[4]	63 (3)	4.8	(0.99-13.29)
JUNE	**(mean cluster size = 49.3)**							
FsRB +ve	1972 (10)	0.5	(0.1-0.9)	1.5 (0.02)	(0.24-0.93)	40 (7)	17.5	(7.34-32.78)
FsRB +ve +/- NsRB +ve +/- UsRB +ve	1972 (19)	1.0	(0.3-1.6)	2.05 (0.012)	(0.58-1.50)	40 (11)	27.5	(14.60-43.89)

Table 85 Individual and herd prevalence of cattle brucellosis using different interpretation criteria for seropositivity for the March and June surveys
([1] By Cochran's procedure; [2] By Paul and Zaihra's method; [3] By Fisher's method; [4] Finite population correction)

8.3.1.1 Cross-sectional survey March 2011

Screening of 1724 cattle sera in the field yielded 10 positives (Table 86). All animals were female and sexually mature. Household level data for the three positive herds out of 63 households sampled are summarised in Table 86. Brucellosis was ranked as the number one disease for all positive herds by the household head.

ID March	*SN*	*Block*	*Age (yrs)*	*Lifestage*	*No. calves*	*Year moved KGR*	*Herd size*	*Bakale rank*	*Clinical signs observed in herd*		
									AB	RB	HG
1006	1	1	7	Cow	NS	NS	180	1	Y	Y	Y
	2	1	7	Cow	0						
1017	3	1	8	Cow	NS	2009	128	1	Y	N	N
	4	1	7	Cow	NS						
	5	1	7	Cow	4						
	6	1	3	Heifer	0						
	7	1	8	Cow	NS						
2028	8	2	8	Cow	5	2003	150	1	Y	N	Y
	9	2	8	Cow	5						
	10[1]	2	4	Cow	2						

Table 86 Age, sex, lifestage and parity of FsRB positive cattle and herd-level data for positive herds for March survey
(NS- not specified in questionnaire, AB- abortion, RB- reduced breeding or infertility, HG- hygroma,
[1] *Brucella* isolated from hygroma sample from this animal).

Table 87 and Table 88 summarise individual and household-level risk factors respectively. The block of origin of cattle, age of cattle and brucellosis rank were the found to be significantly associated with brucellosis infection at the 5% level.

Variable	*N (+ve)*	*% positive (95% CI)[1]*	*Odds ratio (95% CI)[1]*	*Chi-square (DF, p)[2]*	*Fisher's (p)[3]*
Block					
1	636 (7)	1.10 (0.44-2.25)	4. 02 (0.91-24.19)	4.736 (1, 0.030)* 4.733 (1, 0.030)*[4]	0.035*
2,3,4,5	1088 (3)	0.28 (0.06-0.80)			
Sex					
Female	1170 (9)	0.77 (0.04-1.46)	4.13 (0.57-181.43)	2.129 (1, 0.145) 2.127 (1, 0.145)[4]	0.076
Male	534 (1)	0.19 (0.00-1.04)			
Age					
≥4 y.o.	820 (8)	0.98 (0.42-1.91)	4.27 (0.85-41.32)	3.976 (1, 0.046)* 3.974 (1, 0.046)*[4]	0.045*
< 4 y.o.	868 (2)	0.23 (0.03-0.83)			

Table 87 Investigation of individual level risk factors for cattle FsRB positives from March survey
([1] Fisher's exact CI; [2] Pearson's chi-square; [3] Fisher's one-tailed test; [4] Upton's adjusted chi-square; * statistical significance at 5% level)

Variable	*No. herds (positive)*	*% positive (95% CI)1*	*Fisher's (p)2*
Herd size			
Herd size >70	23 (3)	13.0 (2.78-33.59)	0.061
Herd size <=70	34 (0)	0 (0.00-12.67)	
Migration			
Yes	27 (2)	7.41 (0.91-24.29)	0.460
No	30 (1)	3.33 (0.08-17.22)	
Brucellosis rank			
Responder ranking of 1 for brucellosis	4 (3)	75 (19.41-99.37)	0.000*
Responder ranking of <1 for brucellosis	53 (0)	0 (0.00-7.11)	
Brucellosis case reports			
Responder reports cattle brucellosis cases	27 (3)	11.11 (2.35-29.16)	0.14
Responder does not report cattle bruce.	24 (0)	0.00 (0.00-14.25)	

Table 88 Investigation of herd level risk factors for cattle FsRB positives from March survey

([1] Fisher's exact CI; [2] Fisher's one-tailed test; * statistical significance, p<0.01)

8.3.1.2 Cross-sectional survey June 2011

10 cattle out of 1972 animals sampled (0.5%) were found to be positive in the field (FsRB), and this increased to 19 positives including sera found to be positive during re-screening in Nigeria and UNAV under lab conditions (see Table 85). Serological and bacteriological results are detailed for each animal in Table 89. Most females were sexually mature cows. Two *Brucella* strains were isolated, one from a vaginal swab and the other from a milk sample. Four males males were positive. Six of the ten infected households were new-immigrants to KGR, having settled in 2011 (Table 90). Herd size was over 93 for seven out of the 11 positive households and all HH but two reported abortions, stillbirths and/or birth of weak calves. Less than half of positive households reported having bakale (brucellosis) in their herd; data on transhumance practice was limited because only four households were old settlers. Three out of four old-settler households reported going on transhumance.

Herd ID	*SN*	*Age (yrs)*	*Sex*	*Lifestage*	*Calves*	*FsRB*	*NsRB*	*UsRB*	*Bact*
1004	1	5	F	Cow	2	0	0	ND	+ (vag swab)
2003	2	2	F	Heifer	0	0	+	+	
	3	6	M	Fattening male	NA	+	+	+	
	4	4	M	Breeding male	NA	+	+	+	
	5	5	F	Cow	1	0	+	+	+ (milk)
	6	3	M	Breeding male	NA	+	+	+	
2004	7	5	M	Breeding male	NA	+	0	0	
2007	8	7	F	Heifer	0	+	+	0	
2011	9	13	F	Cow	6	+	0	0	
3001	10	5	F	Heifer	0	+	0	0	
	11	6	F	Cow	1	+	0	0	
3002	12	4	F	Heifer	0	0	0	+	
3005	13	7	F	Cow	5	0	0	+	
4001	14	4	F	Cow	1	+	0	0	
	15	9	F	Cow	5	0	0	+	
5002	16	3	F	Heifer	0	0	0	+	
6001	17	4	F	Heifer	0	0	0	+	
	18	7	F	Cow	2	+	+	+	
	19	7	F	Cow	2	0	0	+	

Table 89 Characteristics and diagnostic results of positive cattle, June survey

ID June	Year	Herd size	Abortion, stillbirth or weak calf[1]	Bakale in herd[2]	Mig
1004	2011	107	3	Yes	NA
2003	2011	320	5	Yes	NA
2004	NS	110	0	No	Yes
2007	1990	58	0	Yes	Yes
2011	1993	24	2	No	No
3001	2011	93	5	No	NA
3002	2011	36	1	No	NA
3005	1991	41	1	No	Yes
4001	2011	1500	41	No	NA
5002	2001	120	6	Don't know	Yes
6001	2011	193	13	Yes	NA

Table 90 Herd-level data for seropositive/bacteriologically positive cattle herds, June survey

([1] calculated by adding number of abortions, stillbirths and weak born calves in herd in last one year; [2] HHH was asked if he had bakale in his herd; NS- not specified; NA-Respondent could not answer question as new immigrant)

Individual and HH level risk factor analysis is summarised in Table 91 and Table 92 respectively. Only age was statistically significant at the 5% level.

Variable	*No.tested (+ve)*	*% positive (95% CI)[1]*	*Comp.*	*OR (95% CI)[1]*	*Chi-square (DF, p)[2]*
Block					
1	459 (1)	0.22 (0.01-1.21)			
2	659 (8)	1.21 (0.53-2.38)	1&2	5.628	3.986 (5, 0.209)
3	225 (4)	1.78 (0.49-4.49)	1&3	8.290	4.726 (5, 0.140)
4	488 (2)	0.41 (0.05-1.47)	1&4	1.885	0.282 (5, 0.989)
5	84 (1)	1.19 (0.03-6.46)	1&5	5.518	1.323 (5, 0.768)
6	48 (3)	6.25 (1.31-17.20)	1&6	30.533	10.006 (5, 0.008)*
Sex					
Female	1392 (15)	1.08 (0.60-1.77)		1.54 (0.49-6.42)	0.601 (1, 0.438) 0.600 (1, 0.438)[3]
Male	571 (4)	0.70 (0.19-1.78)			
Age					
≥ 4 y.o.	991 (16)	1.61 (0.93-2.61)		5.29 (1.51-28.40)	8.704 (1, 0.003)* 8.699 (1, 0.003)*[3]
< 4 y.o.	970 (3)	0.31 (0.06-0.90)			

Table 91 Investigation of individual level risk factors for cattle interpreted as brucellosis positive from June survey using criteria discussed in text for parallel serological testing
([1] Fisher's exact CI; [2] Pearson's chi-square; [3] Upton's adjusted chi-square; * statistically significant p<0.05)

Variable	*No. HH (+ve)*	*% positive (95% CI)[1]*	*Odds Ratio (95% CI)[1]*	*Chi-square (DF, p) [2, 3]*	*Fisher's (p)[4]*
Year HH moved to KGR					
New migrant (2011)	14 (6)	42.86 (17.66-71.14)	3.75 (0.65-22.63)	3.128 (1, 0.077)	0.084
Old settler (<2011)	24 (4)	16.67 (4.74-37.38)		3.046 (1, 0.081)	
Herd size					
≥90	20 (7)	35.00 (15.39-59.22)	2.02 (0.39-11.47)	0.936 (1, 0.333)	0.271
<90	19 (4)	21.05 (6.05-45.57)		0.912 (1, 0.340)	
Abortions/stillbirths/ or birth of weak calves reported in the last one year					
Yes	29 (9)	31.03 (15.28-50.83)	2.38 (0.36-26.75)	0.999 (1, 0.317)	0.278
No	11 (2)	18.18 (2.28-51.78)		0.972 (1, 0.324)	
Responder reports of cattle brucellosis cases in herd					
Yes	16 (4)	25.00 (7.27-52.38)	1.00 (0.33-2.99)	0.000 (1, 1.000)	0.640
No	24 (6)	25.00 (9.77-46.71)		0.000 (1, 1.000)	
Herd size change over 1 year					
Decrease	14 (4)	28.57 (8.39-58.10)	1.09 (0.19-5.61)	0.012 (1, 0.911)	0.596
Increase	26 (7)	26.92 (11.57-47.79)		0.012 (1, 0.912)	

Table 92 Investigation of herd level risk factors for cattle interpreted as brucellosis positive from June survey using criteria discussed in text for parallel serological testing
([1] By Fisher's method; [2] Pearson's chi-square; [3] Upton's chi-square t; [4] Fisher's one-tailed test* statistically significant at 5% level)

Productivity between brucellosis-positive and brucellosis-negative animals was compared through a proxy indicator calculated by dividing the number of calves born by the age of the cow (for sexually mature animals over four years old only). The

null hypothesis was that there is no difference in productivity (calf/age) between positive and negative cows. The alternative hypothesis is that productivity is lower in brucellosis-infected herds. Table 93 shows that a statistically significant difference does not exist at the 5% level.

Figure 96 shows that highly productive cows are less affected by brucellosis than low/moderately productive cows giving birth to less than 0.6 calves per year. Figure 97 shows that the median and mean 'productivity' is higher for brucellosis negative than for positive cows.

Brucellosis infection status	*N*	*Median 'calves/year'*	*Average rank*
0	659	0.3750	336.6
1	10	0.2857	269.4
Overall	669		335.0

Table 93 Kruskal-Wallis Test for brucellosis positivity versus calves/year

(H = 1.17 DF = 1 P = 0.279; H = 1.18 DF = 1 P = 0.277 [adjusted for ties])

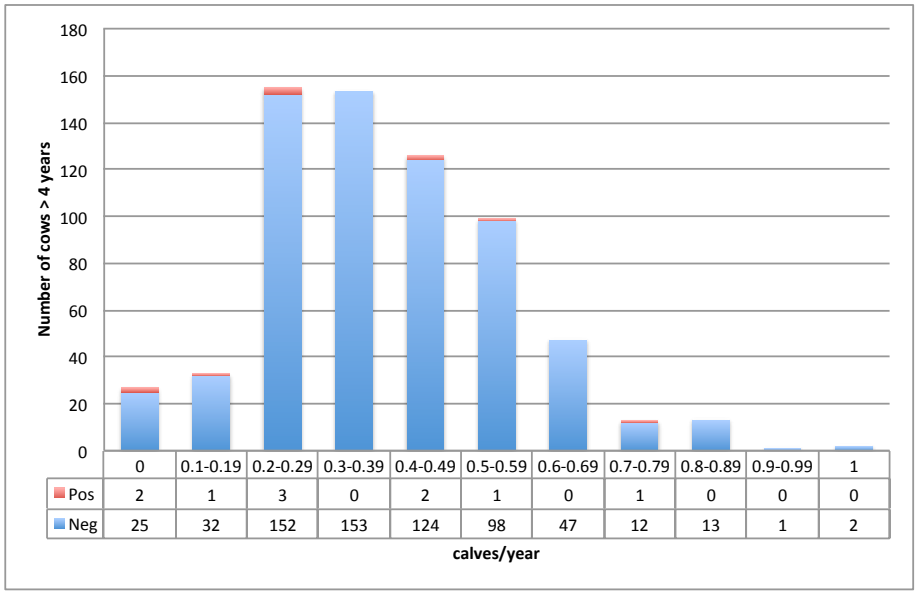


Figure 96 Frequency histogram of productivity proxy for brucellosis positive and negative cows
(Red- cows found to be RBT positive, blue- cows found to be RBT negative)

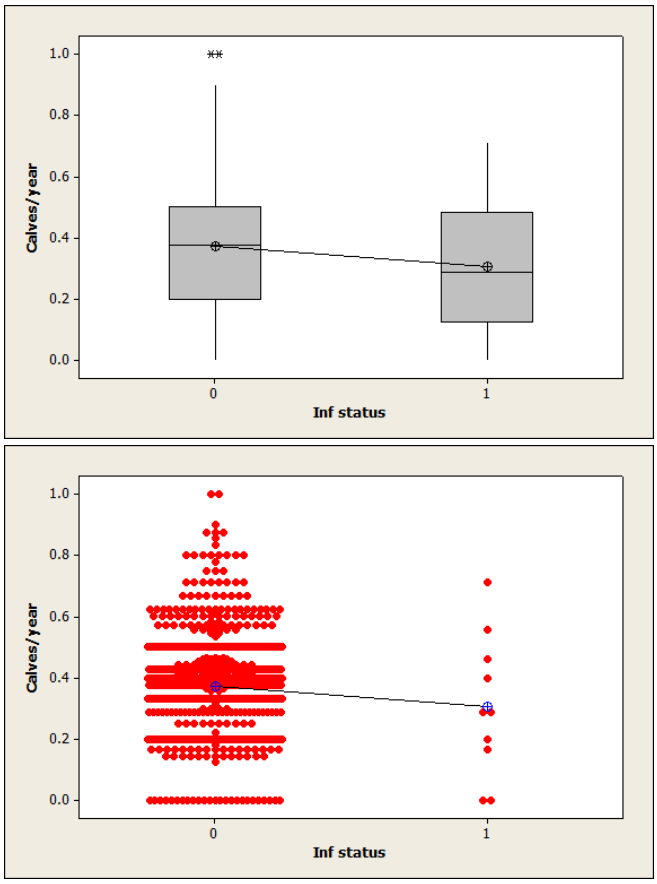


Figure 97 'Productivity' (calves/age of cow) of brucellosis positive and negative sexually mature cows
(0- cows found to be RBT negative; 1- cows found to be RBT positive)

8.3.2 Sheep

The number of sheep found to be positive with sRBT was consistently low across the three surveys (Table 94).

Interpretation	*N sheep (+ve)*	*Ind prev*	*95% CI (proportion)*[1]	*N flocks (+ve)*	*Herd prev*	*95% CI (proportion)*[1]
March (mean cluster size = 10.6)						
FsRB +ve	275 (1)	0.4	(0.01-2.01)	26 (1)	3.8	(0.10-19.64)
June (mean cluster size = 9.9)						
FsRB +ve	119 (0)	0	(0.00-3.05)	12 (0)	0	(0.00-26.46)
October (mean cluster size 14.1)						
FsRB +ve	718 (2)	0.3	(0.03-1.00)	51 (1)	3.9	(0.48-13.46)
FsRB +ve +/- UsRB +ve	718 (4)	0.6	(0.15-1.42)	51 (3)	5.9	(1.23-16.24.46)

Table 94 Individual and herd prevalence of sheep brucellosis using different interpretation criteria for infection for the March, June and October surveys
([1] By Fisher's method)

8.3.2.1 Cross-sectional survey March 2011

Brucellosis results must be interpreted in the context of flock composition (Figure 98 and Table 95). The age and sex structure of small ruminant flock data are summarised here below. The highest frequency age group in sheep flocks is 2-2.5 years. Sexual maturity occurs at one year old for both male and female. Flocks are made up of a vast majority of females (82%), the majority of which are reproductively active ewes.

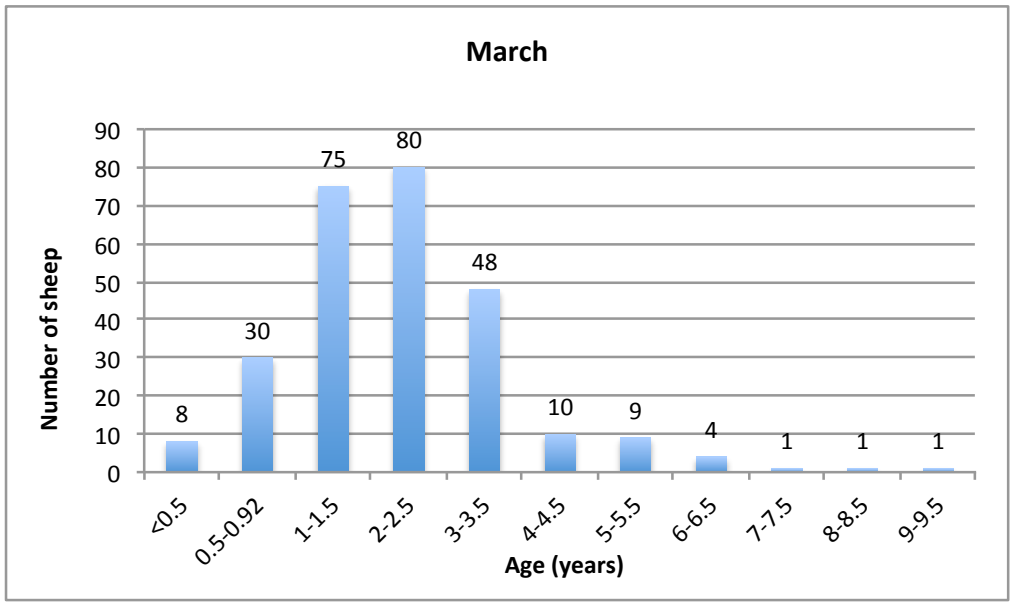


Figure 98 Frequency distribution of age of sheep sampled during March survey

Lifestage	*Description*	*N*	*%*
Males		**48**	**18.0**
Lamb male	< 0.5 y.o. male	4	1.5
Juvenile male	0.5-0.92 y.o. male	16	6.0
Ram	≥1 y.o. male	28	10.5
Females		**219**	**82.0**
Lamb female	< 0.5 y.o. female	4	1.5
Juvenile female	0.5-0.92 y.o. female	14	5.2
Gimmer	≥1 y.o. female no lambs	9	3.4
Ewe	≥1 y.o. female lambs	192	71.9
TOTAL		**267**	**100.0**

Table 95 Number and percentage of sampled sheep in each lifestage category for March survey

A single sRBT positive sheep was identified during field screening of the 275 samples collected during March 2011, a three year old ewe from a household in Block 1 (1006), which also had positive cattle.

8.3.2.2 Cross-sectional survey June 2011

As for the March survey, the highest frequency age group is the 2-2.5 years old category (Figure 99). Females (78%) and ewes (51%) dominate the flock (Table 96).

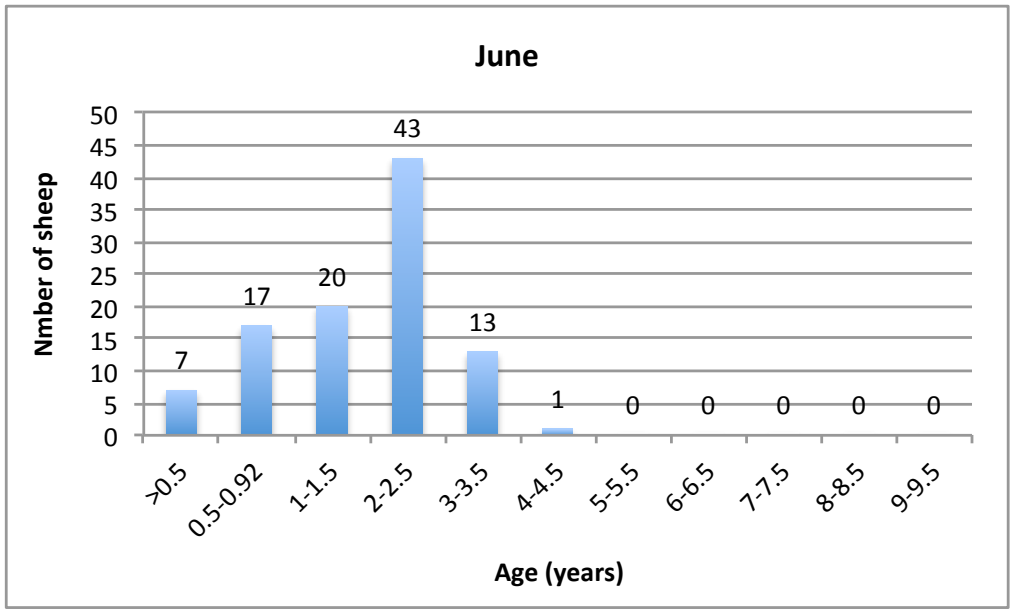


Figure 99 Frequency distribution of age of sheep sampled during June survey

Lifestage	*Description*	*N*	*%*
Males		**26**	**21.8**
Lamb male	< 0.5 y.o. male	2	1.7
Juvenile male	0.5-0.9 y.o. male	5	4.2
Ram	≥1 y.o. male	16	13.4
Females		**93**	**78.2**
Lamb female	< 0.5 y.o. female	5	4.2
Juvenile female	0.5-0.9 y.o. female	12	10.1
Gimmer	≥1 y.o. female no lambs	0	0.0
Ewe	≥1 y.o. female lambs	61	51.3
TOTAL		**119**[1]	**100.0**

Table 96 Number and percentage of sampled sheep in each lifestage category for June survey

([1] data on age missing for 18 animals hence discrepancy between totals)

None of the 119 sheep sampled during June 2011 were seropositive using the field sRBT.

8.3.2.3 Cross-sectional survey October 2011

The age composition of sheep for the October 2011 survey differed with the most frequent age category being 1-1.5 years old (Figure 100 and Table 97). The younger

flock profile was due to the sampling period being a few months after one of the lambing seasons.

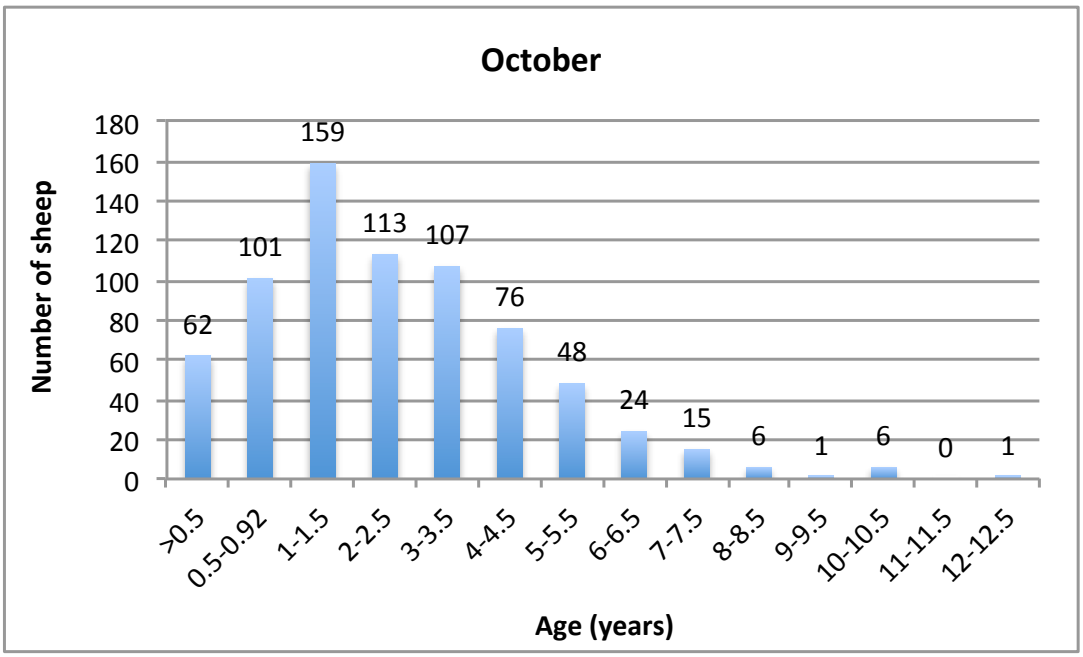


Figure 100 Frequency distribution of age of sheep sampled during October survey

Lifestage	*Description*	*N*	*%*
Males		**134**	**18.6**
Lamb male	< 0.5 y.o. male	24	3.3
Juvenile male	0.5-0.9 y.o. male	38	5.3
Ram	≥1 y.o. male	72	10.0
Females		**585**	**81.4**
Lamb female	< 0.5 y.o. female	38	5.3
Juvenile female	0.5-0.9 y.o. female	63	8.8
Gimmer	≥1 y.o. female no lambs	94	13.1
Ewe	≥1 y.o. female lambs	390	54.2
TOTAL		**719**	**100.0**

Table 97 Number and percentage of sampled sheep in each lifestage category for October survey

Two sheep of 718 sampled were positive with field sRBT screening (FsRB). For one sample there was insufficient serum for rescreening and the other was negative using sRBT. Screening of 696 of the 718 samples in UNAV with the sRBT under laboratory conditions (UsRB) detected two positives. All sRBT positive sheep were sexually mature females (Table 98). None of the sRBT positive sheep belonged to households sampled in June and cattle infection status is unknown for these

households. One weak sRBT positive sample came from a new-immigrant household with infected cattle (HH 4001 according to June ID code).

HH ID	Age (yrs)	Sex	Lambs	FsRB	UsRB	Cattle sampled	Year moved
1009	4	F	4	-	+	No	NS
	2	F	2	-	+		
2022	6	F	6	+	-	No	2008
4010	5	F	3	+	ND	No	1989
4003 (4001 June ID)	5	F	7	-	+/-	Yes (pos)	2011

Table 98 Characteristics and serological results of sRBT positive-sheep, October survey

(ND- not done, NS- not specified)

Because of the low number of positives risk-factor analysis has not been undertaken.

8.3.3 Goats

Initial screening with sRBT showed no seropositives for the March nor October survey. Serum re-screening at UNAV from the October survey revealed two sRBT positives (Table 99).

INTERPRET.	*N goats (+ve)*	*Ind prev*	*95% CI (proportion)*[1]	*n herds (+ve)*	*Herd prev*	*95% CI (proportion)*[1]
March (mean cluster size = 8.8)						
FsRB +ve	79 (0)	0	(0.00-4.56)	9 (0)	0	(0.00-33.63)
October (mean cluster size = 13.9)						
FsRB +ve	779 (0)	0	(0.00-0.47)	51 (0)	0	(0.00-6.98)
FsRB +ve +/- UsRB +ve	779 (2)	0.3	(0.03-0.92)	51 (1)	2.0	(0.05-10.45)

Table 99 Individual and herd prevalence of goat brucellosis using different interpretation criteria for infection for the March and October survey

([1] By Fisher's method)

8.3.3.1 Cross-sectional survey March 2011

The age and sex of goats sampled during the March survey was similar to that observed in sheep for the March and June surveys (see Figure 101 and Table 100).

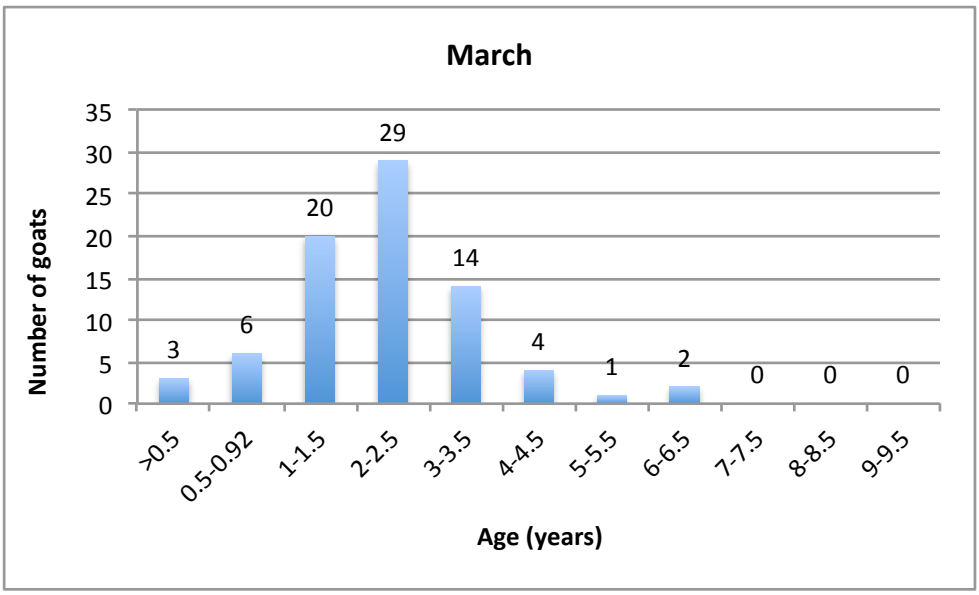


Figure 101 Frequency distribution of age of goats sampled during March survey

Lifestage	*Description*	*N*	*%*
Males		**4**	**5.1**
Kid male	< 0.5 y.o. male	1	1.3
Juvenile male	0.5-0.9 y.o. male	0	0.0
Buck	≥1 y.o. male	3	3.8
Females		**75**	**94.9**
Kid female	< 0.5 y.o. female	2	2.5
Juvenile female	0.5-0.9 y.o. female	6	7.6
Doe no kid	≥1 y.o. female no lambs	0	0.0
Doe	≥1 y.o. female lambs	67	84.8
TOTAL		**79**	**100.0**

Table 100 Number and percentage of sampled goats in each lifestage category for March survey

No goats were seropositive with sRBT screening in the field during this survey.

8.3.3.2 Cross-sectional survey October 2011

The goat population sampled during the October 2011 had a higher proportion of young animals (Figure 102 and Table 101) due to the recent kidding season.

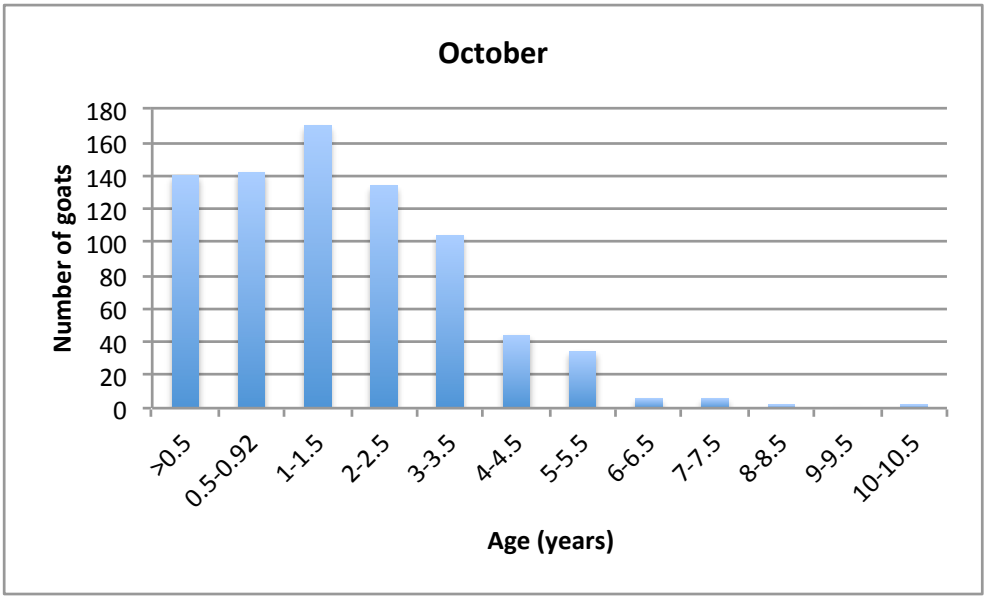


Figure 102 Frequency distribution of age of goats sampled during October survey

Lifestage	*Description*	*N*	*%*
Males		**140**	**17.9**
Kid male	< 0.5 y.o. male	51	6.5
Juvenile male	0.5-0.9 y.o. male	49	6.3
Buck	≥1 y.o. male	40	5.1
Females		**644**	**82.1**
Kid female	< 0.5 y.o. female	89	11.4
Juvenile female	0.5-0.9 y.o. female	93	11.9
Doe no kid	≥1 y.o. female no lambs	40	5.1
Doe	≥1 y.o. female lambs	422	53.8
TOTAL		**784**	**100.0**

Table 101 Number and percentage of sampled goats in each lifestage category October survey

Field screening of the 779 goat sera from the October survey with sRBT yielded no seropositives. Re-screening of the 748 samples out of 779 sent to UNAV yielded two positive sRBT results from the same herd (Table 102). This household was not sampled in June and cattle infection status is unknown. Because of the low number of positives risk-factor analysis has not been undertaken.

ID Oct	***Age (yr)***	***Sex***	***Offspring***	***FsRB***	***UsRB***	***Cattle samped***	***Year moved***
1013	0.25	F	0	-	+	N	1989
	1	F	1	-	+		

Table 102 Characteristics and serological results of sRBT positive goats, October survey

8.3.4 Humans

8.3.4.1 Cross-sectional survey October 2011

A total of 1126 persons (six years or older) were sampled of which 56% were male. The highest frequency age group was 11 to 20 years for males and females. The age and sex distribution of individuals sampled is shown in Figure 103 and Table 103.

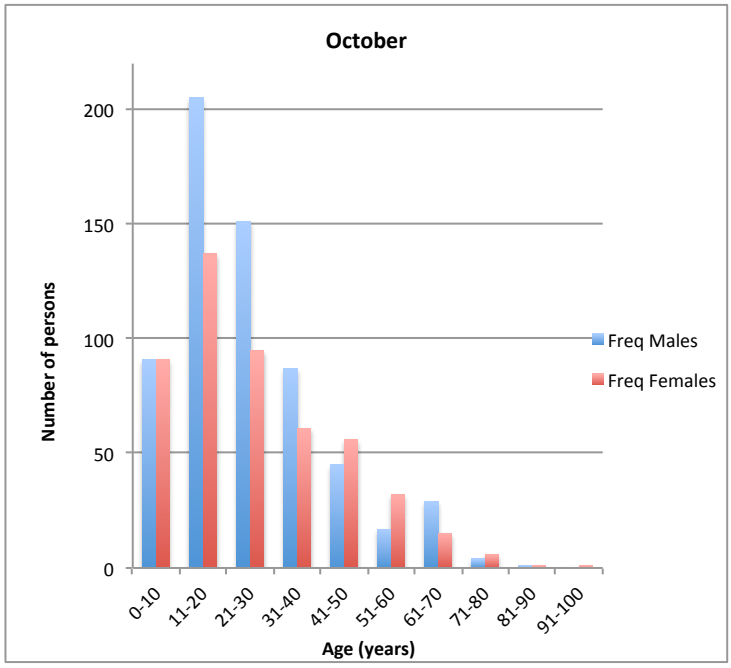


Figure 103 Frequency distribution of age of persons sampled during October survey

Age (yrs)	*No. males*	*% males*	*No. females*	*% females*	*Total*
0-10	91	14.4	91	18.4	182
11-20	205	32.5	137	27.7	342
21-30	151	24.0	95	19.2	246
31-40	87	13.8	61	12.3	148
41-50	45	7.1	56	11.3	101
51-60	17	2.7	32	6.5	49
61-70	29	4.6	15	3.0	44
71-80	4	0.6	6	1.2	10
81-90	1	0.2	1	0.2	2
91-100	0	0.0	1	0.2	1
Total	630	100.0	495	100.0	1125
%	56		44		100

Table 103 Number and percentage of sampled persons in each age and sex category for October survey

None of the 1126 humans screened under field conditions were found to be positive. Re-screening of 976 of sera under laboratory conditions revealed that 29 sera were positive to the sRBT, however these were all found to be negative to SAT, Coombs and Brucellacapt®. All positive sRBT samples have been interpreted as false positives (see Chapter 7). The conclusion of the serological investigations is that no human positives were detected during the October cross-sectional survey.

8.3.5 Prevalence and imperfect tests

The analysis refers to cattle data only.

8.3.5.1 True individual prevalence, predictive values and likelihood ratios

Individual prevalence, predictive values and likelihood ratios were estimated from the March and June FsRB testing results based on the input values specified in Table 104. The true prevalence is estimated at 0.4 and 0.3% for the March and June surveys respectively (Table 105). There is a 0.95 probability that the true individual prevalence of cattle brucellosis in KGR is between 0.1 and 0.9% and 0.1 and 0.7% for the March and June surveys respectively (Table 105). There is a 0.66 or 0.60 probability that a cow or bull positive according to FsRB is positive in the March and June surveys respectively (Table 105). There is a probability of 1 that a cow or bull negative with to FsRB is a true negative. A positive result is 491 times as likely to come from cattle with brucellosis as from an animal without the disease. A negative result is 0.02 times as likely to come from an animal with brucellosis as from an animal without disease.

Inputs	March	June
Sample size	1724	1972
Number FsRB positives	10	10
Test (sRBT) sensitivity[1]	0.981	0.981
Test (sRBT) specificity[1]	0.998	0.998
Confidence level	0.95	0.95

Table 104 Values introduced into Epi Tools to estimate true prevalence and predictive values

[1] Sensitivity and specificity values as per Greiner et al. (2009)

Parameters	*March survey*			*June survey*		
	Estimate	*Lower 95% CI*	*Upper 95% CI*	*Estimate*	*Lower 95% CI*	*Upper 95% CI*
Apparent prevalence (Wilson CL)	0.006	0.003	0.011	0.005	0.003	0.009
Blaker's Exact CL	0.004	0.001	0.009	0.003	0.001	0.007
Positive predictive value	0.657			0.607		
Negative predictive value	1			1		
Likelihood ratio +ve	490.5			490.5		
Likelihood ration -ve	0.019			0.019		

Table 105 Prevalence estimates and 95% CI, predictive values and likelihood ratios

8.3.5.2 Aggregate sensitivity and specificity

If the minimum prevalence is assumed to be 0.5% as per the individual prevalence determine by FsRB screening for the March survey, the probability of observing 2, 5 and 3 or fewer test positives in a sample of 16, 100 and 32 cattle drawn from a population of 180, 250 and 150 cattle respectively is 0.999 (Table 106). There is a very low probability (0.001) of missing infected herds and one is only 0.01% confident that the disease is absent at a minimum prevalence of 0.5%. The aggregate sensitivity is therefore 99.99%, indicating there is a high probability of detecting infected herds based on the assumptions specified in Table 106.

The p_0 values for herds classified as infected during the March survey are 0.05, 0.01 and 0.01%: which corresponds to the probability of observing 2, 5 and 3 reactors respectively or more in a sample of 16, 100 and 32 cattle respectively drawn from a disease free herd of 180, 250 and 150 cattle respectively. One can be 99.95%, 99.99% and 99.99% confident respectively that the herds are diseased. There is very low probability of incorrectly classifying a healthy herd as being diseased. There is a 0.9995, 0.9999 and 0.9999 probability of classifying a healthy herd as being healthy. The aggregate specificity for the three herds categorised as infected during the March survey is 99.95, 99.99 and 99.99% (Table 106).

For the June survey the minimum prevalence was set at 0.6% as per the individual prevalence value obtained in this survey with FsRB screening. Table 106 demonstrates that except for herd 2003 where 3 cattle were found to be FsRB positive, the fact that for most herds only one cattle tested FsRB positive reduces the aggregate sensitivity values obtained for June herds as compared with the values

obtained for March herds. For all herds except 4001 and 6001, however, aggregate sensitivity is still over 99%. The probability of observing 1 or fewer FsRB positive cattle in a sample of 81 and 57 cattle drawn from herds of 1500 and 170 cattle respectively is 11 and 4% respectively. Hence there is an 11 and 4% probability, with these parameters, of missing an infected herd. In other words we are only detecting 89 and 96% of infected herds respectively with this level of interpretation. The results for aggregate specificity as based on the level of interpretation of herd 2004, 2007, 2011, 4001 and 6001 show a lower probability (0.85-0.95) of correctly classifying health herds as being healthy than that obtained as per parameters defined with the March data. Thus, one can only be 85-95% confident that a herd is affected, based on the parameters of herds 2004, 2007, 2011, 4001 and 6011 sampled in June. Hence there is a 5-15% probability of observing 1 reactor or more in samples of cattle drawn from a disease-free herd.

Survey	*Herd ID*	*Sample size (y)*	*No. positives (x)*	*Prevalence (x/y)*	*Herd size (z)*	*Se_{agg} (p_1) (%)*	*(1- p_1) (%)*	*Sp_{agg} (1-p_0) (%)*	*(p_0) (%)*
March	1006	16	2	0.13	180	99.99	0.01	99.95	0.05
	1007	100	5	0.05	250	99.99	0.01	99.99	0.01
	2028	32	3	0.09	150	99.99	0.01	99.99	0.01
June	2003	87	3	0.03	220	99.97	0.03	99.93	0.07
	2004	34	1	0.03	50	99.79	0.21	93.42	6.58
	2007	56	1	0.02	58	99.43	0.57	89.39	10.61
	2011	25	1	0.04	25	99.88	0.12	95.12	4.88
	3001	82	2	0.02	93	99.94	0.06	98.81	1.19
	4001	81	1	0.01	1500	88.64	11.36	85.03	14.97
	6001	57	1	0.02	170	96.11	3.89	89.22	10.78

Table 106 Aggregate sensitivity and specificity estimates for herds with one or more FsRB positive in the March and June survey

Se_{agg} (p_1) - aggregate sensitivity or probability of observing x number of positives or less in a sample of y cattle for a herd of z cattle in which the individual prevalence is 0.6% for March and 0.5% for June survey

(1- p_1) - probability of missing disease in a sample of y cattle for a herd of z cattle in which the prevalence is 0.6% for March and 0.5% for June

Sp_{agg} (1-p_0) - aggregate specificity or probability of correctly classifying a healthy herd of z cattle as being healthy from a sample of y cattle

(p_0)- probability of observing x reactors or more in a sample of y cattle drawn from a disease –free herd of z cattle

8.4 Discussion

8.4.1 Prevalence

8.4.1.1 Brucellosis in cattle

The epidemiological picture for brucellosis cattle in the KGR is one of low individual prevalence and higher herd prevalence. Individual prevalence in cattle was found to be 0.6% (0.0-1.3%, 95% CI) and 0.5% (0.1-1.2%) during field screening with sRBT for the March and June surveys respectively. Re-screening of samples collected in June in the laboratory yielded a few more positives, increasing the prevalence to 1.0% (0.3-1.6%, 95% CI).

These values are lower than individual prevalence estimates reported for other recent studies undertaken in extensive pastoralist systems in Northern Nigeria (Mbuk et al., 2011, Farouk et al., 2013, Bertu et al., 2012, Maurice et al., 2013, Ocholi et al., 1996). In fact a recent large seroprevalence survey undertaken in Adamawa, Kaduna and Kano states (North Nigeria) found 45% of cattle (n=1244) in pastoralist herds to be seropositive (Mai et al., 2012). The disparity between the present and the study of Mai and colleagues (2012) is unclear, but may be due to differences in sampling approach, location and/or use of diagnostics. For the Mai et al. (2012) study, herd selection was based on proximity to a reliable laboratory and farmer cooperation, a potential source of bias. Use of a serial testing system (samples positive or inconclusive with RBT confirmed with cELISA) by Mai et al. (2012) may also account for the difference. RBT antigen for this study versus the Mai et al. (2012) survey also differed. Their study used the VLA antigen, which, although standardised according to OIE criteria, is not validated against panels of reference positive and negative sera (see standardisation section in Chapter 7). Competitive ELISA kits were used according to manufacturer instructions and were never validated under local conditions (cut-offs established in brucellosis-free and good hygienic conditions cannot be extrapolated to endemic areas (Greiner et al., 2009)).

The findings of the study agree with early official veterinary records and investigators, which did not consider brucellosis a hazard in extensively managed herds (Banerjee and Bhatty, 1970, Anonymous, 1958, Esuruoso, 1974a, Eze, 1978).

Esuruoso wrote: *"Cattle…in nomadic herds…on the move… are not likely to accumulate infection or spread it from one animal to the other as in settled herds. This factor, and the intense heat of the sun in fairly open country (Sudan Savannah zone) will provide some of the reasons for the low infection rate…in the northern herds… It would appear, therefore, that nomadic herding in Nigeria imposes a natural limit on the rate of brucellosis infection in cattle."*

This observation is consistent with the low transmission deemed typical of pastoralist systems (Racloz et al., 2013).

The findings of this study also contrast with reports that transhumance grazing is associated with a high *Brucella* prevalence because of the increased opportunity for animals to come into contact with potentially infected herds during their movement and co-mingling, increasing the risk of transmission (Macpherson, 1994, Omer et al., 2000, Boukary et al., 2013, Mai et al., 2013, Muma et al., 2006). Additionally, overcrowding of animals during temporary housing or herding in kraals is thought to increase the chance of within-herd transmission. Some authors have also argued that transhumant grazing allows interaction of wildlife and livestock, facilitating transmission of disease (Marcotty et al., 2009).

Comparison of individual and herd prevalence across both surveys can only be undertaken using results of the FsRB because conditions and operators were constant. Individual prevalence is almost identical for the March and June survey (0.6% and 0.5% respectively), however, the herd prevalence is much higher for the June survey (4.8% and 17.5% for the March and June surveys respectively). Comparison of the two surveys is not robust due to differences in sampling strategy (see Chapter 2). This disparity in herd prevalence may correspond to an increase in brucellosis transmission as a result of mass-immigration into the KGR and increased cattle density. This is discussed in more detail in the section 8.4.2.5 below.

Despite individual prevalence being low, herd prevalence was found to be higher. March and June prevalence values were found to be 4.8% (0.99-13.29, 95% CI) and 20.0% (9.05-35.65. 95% CI) respectively. In March, more than one cattle was found to be positive per herd for the three positive herds (Table 86), whereas in June six positive herds only had one positive cattle per herd.

What is the relevance or reason for the existence of herds with only one seropositive cattle? Experience from transhumant cattle herds in Spain would suggest that this is neither a unique nor an unexpected epidemiological finding (Blasco, C., personal communication). Screening of such herds with the protein antigen 'brucellin' intradermal skin test would confirm presence of infected 'seronegatives'. Cross-sectional surveys offer a snapshot only of the herd serological status. Serological status of individual animals evolves over time, depending on the time since introduction of infection and reproductive/physiological (e.g. pregnancy). Longitudinal studies would be of interest to monitor evolution of serological status over time. Studies to assess the presence of FPSR would also be valuable.

The rate of homogeneity (ROH) values were 0.05 and 0.01 for the March and June surveys, respectively. These values are lower than that reported by Orjuela et al. (1991), who found a ROH of 0.09 for brucellosis infection in cattle in traditional production systems of Colombia. This would suggest that the within-herd prevalence was lower in the KGR and that within-herd transmission of infection occurs less readily in the KGR than the production systems of Colombia. Explanations for this include: i) resistance of local cattle breeds to infection; ii) herd-level management practices that reduce opportunities for transmission (such as transhumance) (explored in more depth in Chapter 9); iii) lower virulence of *Brucella* strains.

This study is one of only three brucellosis studies in Nigeria that have applied random sampling theory. Because the KGR community was found to be highly mobile, it seems that conditions in the KGR are not dissimilar from other pastoralist communities. This would suggest that the epidemiological situation in other Fulani pastoralist settings is likely to be similar to that observed in the KGR. Studies in pastoralist communities in other geographical locations of Nigeria would be necessary to confirm if this extrapolation is valid.

Bacteriology on cattle samples confirmed presence of *B. abortus* biovar 3. Only 5 studies have provided bacteriological data for cattle since brucellosis was first reported in Nigeria in 1927 (Banerjee and Bhatty, 1970). In the West, studies in range cattle and in a University herd described the isolation of *Brucella* strains, probably *B. abortus* (Esuruoso, 1974b). *B. abortus* was identified in herds on

government and private farms and in settled Fulani herds in the Centre and North (Bale and Kumi-Diaka, 1981, Eze, 1978 , Ocholi et al., 2004b). In all 58 *B. abortus* strains were classified as (54 as biovar 1; 1 as biovar 2; 2 as biovar 3 and 1 as biovar 4. Re-examination of 20 biovar 1 isolates showed biovar 3 characteristics (the dominant biovar in countries proximal to Nigeria (Sanogo et al., 2013a).

8.4.1.2 Brucellosis in small ruminants

Seroprevalence in sheep and goats was consistently low across the three surveys. Studies undertaken in pastoralist settings in Northern Nigeria are scarce. Bertu et al. (2010) reported prevalence rates ranging between 5.0-13.3% for sheep and 7.4-16.3% for goats in Plateau State. Kaltungo et al. (2013) found a prevalence of 25.8% in goats in Kaduna State. Both studies used the RBT. The difference between the low prevalence obtained in the KGR and those of other recent studies is unclear, but could be due to differences in RBT antigen, sampling approach and location. Some abattoir studies found low prevalence values (0.3%–0.9% and 0-2.4% for goat and sheep, respectively), and since animals come mostly from the North regardless of the location of the abattoir, reflect the situation in the North (Cadmus et al., 2006, Brisibe et al., 1993, Okewole et al., 1988, Falade, 1980).

Bacteriology was not performed in small ruminants to confirm infection and determine the infecting *Brucella* species. Bacteriological evidence for *Brucella* in small ruminants in Nigeria is scarce. An early study claimed the isolation of *B. abortus* in sheep and goats, but the methodology used in species identification is unclear (Okoh, 1980). B. melitensis biovar 1 (22 strains) and *B. abortus* biovar 1 (8 strains) were isolated from goats in western Nigeria (Falade and Shonekan, 1981). However, the reported biochemical characteristics of the B. melitensis strains are atypical. *Brucella melitensis* was recently described in sheep and goats in northern Nigeria but the ten strains were not definitively typed (Bale et al., 2003b). A study in Bauchi (central Nigeria) clearly demonstrated *B. abortus* but not *B. melitensis* in sheep (Ocholi et al., 2004b). Interestingly, seven *B. abortus* strains were isolated from sheep reared in contact with infected cattle (Ocholi et al., 2005). Although *B. abortus* preferentially infects cattle, it is known to persist in sheep (Luchsinger and

Anderson, 1979) and the significance of *B. abortus* infection in small ruminants in the mixed breeding systems of sub-Saharan Africa requires further investigation.

The picture from the KGR leads to the speculation that *B. abortus* may be circulating amongst its preferential host (cattle) with occasional spill-over to small ruminants. Unfortunately there is limited data on cattle and sheep or goat co-infection at household level. One infected cattle household sampled in March was also found to have one seropositive sheep. Unfortunately the four seropositive sheep detected during the October survey did not belong to households sampled in October hence the cattle positivity status for these households is unknown. One household sampled in June found to have positive cattle was also found to have a suspicious or weak sheep sample when that household was re-sampled in October. For the two seropositive goats detected in October the issue is the same as for sheep, as these belonged to a household with unknown cattle positivity status. None of the households with negative cattle had seropositive small ruminants. The evidence from this study is insufficient to confirm that *B. abortus* is circulating predominantly amongst its preferential host cattle, with occasional spill-over to small ruminants.

The number of seropositive sheep (five in total across all surveys) was higher than the number of seropositive goats (two overall).

Goats are not grazed with cattle but are managed independently by women. During the wet season, goats are kept within the homestead and are unlikely to have contact with cattle or sheep. This is to avoid goats grazing on crops grown by the household before they have been harvested. Goats are tethered in small goat houses to prevent them from straying from the homestead, and forage is brought to them. Cattle and sheep in contrast are co-grazed and managed by men. Cattle and sheep are taken away from the homestead for grazing during the day. At night, adult cattle and suckling calves are herded in kraals. Older calves are roped to a central point outside the kraal to prevent them from suckling. Sheep are also restrained with ropes to a central point away from the cattle kraal. Sheep are managed with cattle both during the dry and wet season. Management of goats, however, is different during the dry season. Goats are left to scavenge and graze free-range, to make the most of the farmland stubble after harvesting of household crops. Goats have contact with cattle

and/or sheep during the dry season through free-range roaming, as they graze in areas of abundant pasture, which are likely to be the same areas to which cattle and sheep are brought for grazing. Transmission could also occur if they were to come into contact with products of abortion of infected cattle, which are left where voided if the cow aborted away from the homestead.

Opportunities for brucellosis transmission from cattle to goats in KGR appears more limited than for transmission from cattle to sheep. Brucellosis prevalence was lower in goats than in sheep for all surveys. This fits with the observation that cattle have more intimate and frequent contact with sheep than with goats.

8.4.1.3 Brucellosis in humans

The results are inconsistent with a picture of human brucellosis. Non-haemolysed sera found to be seropositive produced only weak agglutination reactions, and all but one had a titre of less than 1/8. Sera were all FsRB, SAT and Coombs negative.

A serum titre of 2 in the RBT and titre of 0 in the SAT and Coombs IgG has been reported for persons that had professional contact with *Brucella* but no clinical signs (Díaz et al., 2011). It is possible that some of the non-haemolysed seropositives had been in contact with the *Brucella* antigen but were not infected.

RBT titres of 16 or greater were found only in haemolysed sera. All five sera gave negative results in FsRB, titres of less than 20 in SAT and Coombs and titres of less than 160/320 to Brucellacapt ®. High RBT titres and negative SAT and coombs titres have not been previously reported suggesting that the RBT agglutination is a false positive result. Rescreening of suspect samples under laboratory conditions confirmed that the original field screening was accurate and that there is no human brucellosis in the KGR. This is an unexpected finding in a context where existence of *Brucella abortus* has been confirmed in cattle and one in which a large proportion of the population engage in risky behaviours such as consumption of raw milk, assisting in animal births, home slaughtering of animals and milk processing (Chapter 9).

Potential explanations include: 1) low pathogenicity of *Brucella abortus* biovar 3 strains; 2) low number of infected animals at herd level may correspond to a low

number of *Brucella* shed in bulk milk (below infectious dose); 3) resistance of local populace to infection through constant low-grade exposure (immunisation effect).

Further studies are needed including: 1) in-vitro and in-vivo virulence studies of the isolated *Brucella abortus* biovar 3a strain; 2) bacteriological studies to determine CFU/infectious dose in bulk milk of infected herds; 3) longitudinal serological and bacteriological studies in humans to confirm absence of human disease.

8.4.2 Risk factors

The risk factor analysis refers to cattle data only.

8.4.2.1 Block of origin

Block of origin as a risk factor for positivity was examined for the March and June surveys. In March, seven out of the ten FsRB positive cattle were from Block 1. Block 1 origin, as compared to origin from any other block was a statistically significant risk factor for seropositivity at the 5% level (Table 87). Overall, two of the three herds found to be seropositive were from Block 1 (Table 86). Block 1 was inhabited by 'wealthier' and elite community members with larger herds, on average, than inhabitants of the other blocks (Chapters 3, 4 and 5). Brucellosis positive cattle may be more likely to come from Block 1 as they come from larger cattle herds, and herd size is a recognised risk factor for the disease.

For the June survey the block of origin was not found to be statistically significant (Table 91). The June survey corresponded to a period shortly after a mass immigration into the KGR as a result of post-election violence. The highest frequency of positive cattle (eight and four) was in blocks that experienced the greatest influx of new settlers (blocks 2 and 3) respectively. Immigration of herds into the KGR may have created conditions for increased transmission of brucellosis. This is discussed in more detail in 8.4.2.5.

8.4.2.2 Sex

Sex is a statistically significant risk factor for brucellosis infection in cattle, with males being more likely to be infected under natural conditions (not artificial insemination) (Moriyon, I., pers. comm.). Investigation of sex as a risk factor for

cattle brucellosis positivity did not show a statistically significant difference between male and female positivity at the 5% level. In KGR herds are predominantly composed of females and this was reflected in the ratio of males to females sampled and screened for brucellosis (see Chapter 5). In March all ten FsRB positive animals were female (Table 86), and in June 15 of the 19 positives were female (Table 89). This is in agreement with Mohammed et al. (2011), who investigated bovine brucellosis in Jigawa State (Nigeria) and found higher infection in females than males.

Three of the four males found to be infected during the June survey were from the same herd, and *Brucella* was isolated from a cow in this herd. This proves that *Brucella* infection 'collects' in the males and highlights their potential role in *Brucella* transmission intra-herd, but also inter-herd if inter-herd breeding is practised. Some livestock keepers lend their bulls to other households for breeding and/or use the bulls of other households for breeding with their cows - another way in which inter-herd transmission can occur.

8.4.2.3 Age

Age (over five years old) was found to be associated with a positive brucellosis status at the 5% level of statistical significance for both June and March surveys (Tables 87 and 91). Eight out of ten of the FsRB positive cattle sampled in March were 7-8 years old. From the June survey, of the nine seropositive females, only one was under four years old (Table 91). Seroconversion usually occurs during the first gestation at around four years old (see Chapter 5). Even though infection with *Brucella* may occur before the first gestation, either through vertical or horizontal transmission, the bacteria evade the immune system through intracellular location in macrophages. During pregnancy the bacteria have a tropism for the placenta due to erythritol production and multiply to such an extent that at this stage activation of the antibody-mediated immunity occurs, which is then detected serologically. However, infrequently, heifers born to infected dams may be seropositive from birth.

The four males found to be infected in June were three, four, five and six years old, hence of sexually maturity creating an opportunities for *Brucella* transmission.

This finding is in agreement with Sanogo et al. (2012), Al-Majali et al. (2009), Mohammed et al. (2011) and Boukary et al. (2013) who reported that cattle above 5, 5, 3, 3 and 1-4 years of age respectively were found to have a higher prevalence rate when compared to younger age groups.

8.4.2.4 Productivity and fertility

To evaluate the impact of brucellosis infection on productivity, a proxy was calculated for the June data, whereby the number of calves was divided by the age of the cow. Productive cows were predicted to have higher calf/year score than less productive cows. Brucellosis positive cows were has a lower median calf/age value (and therefore lower productivity) than negative cows (Figure 97), however this difference was not found to be statistically significant at the 5% level (Table 93).

There is evidence that brucellosis may reduce the fertility and productivity of positive females (Table 86 and Table 89). For the March data, out of the 10 FsRB positive females, one female of seven years old had never had a calf. In June, a five and seven year old cow had never had a calf. In the context of low productivity and long calving interval system, the impact of brucellosis on fertility at herd level cannot be underestimated, even though over all herds (due to the low number of herds infected), this effect is 'diluted' and the impact on productivity less 'visible'.

Fertility is affected by numerous other factors such as nutrition status, trypanosomiasis infections etc. Teasing out these factors to determine which has the greatest impact on overall productivity is impossible without doing case-control studies, which were beyond the scope of this thesis.

The impact of brucellosis positivity on herd size increase or decrease over a one-year period was examined. The data show that no significant difference was found between numbers of brucellosis infected herds that had increased in size and those that had decreased in size. This shows that factors other than brucellosis, such as the necessity to sell animals for cash, have a bigger impact than brucellosis on the overall change in herd size over a one-year period. In depth analysis of herd-level longitudinal data would be needed to establish the impact of brucellosis on herd productivity and herd dynamics.

8.4.2.5 Year moved

The majority of households (six out of ten) found to be positive during the June survey moved to the KGR in 2011. Hence the majority of positive herds belong to new-immigrants. This finding and the higher herd prevalence found in June as compared to that pre-mass immigration (March survey) suggest that mass immigration may have promoted conditions to increase the rate of transmission. The evidence to support this is tenuous. There are issues with comparing the March and June data due to differences in sampling strategy between the two surveys. Individual prevalence was found to be equivalent for both the March and June surveys. Another limitation is that the March and June surveys were conducted during different seasons (end of dry versus beginning of wet respectively) which means that the physiological status of cattle and conditions for transmission is not constant across both surveys. Calving, for example, can be associated with seroconversion, and in areas with a defined calving season, 'peaks' of seropositivity can occur. In the case of the KGR, however, calving occurs mostly during 'yamde' (early dry season, November-December). This means that coincidence with calving season cannot explain the increase in herd prevalence in June as compared to March.

Mass immigration promotes physiological stress in cattle, change in dynamics of contact between infected and non-infected herds, higher cattle density which in turn promotes higher frequency of inter-herd contact and opportunities for transmission. Mohammed et al. (2011) reports that prevalence was higher in cattle densely populated locations of Jigawa State (Nigeria). As demonstrated in Chapter 3, the cattle population of the KGR increased by 77% between April-June 2011, going from a cattle population of 24,000 to 42,000. At the time of the June survey, even transhumant households had returned from transhumance. This huge increase in stocking density may have promoted inter-herd transmission of brucellosis.

Infection rates in new immigrant herds as opposed to older KGR settlers were compared (Table 92). The data show that of the fourteen new immigrant households, six (43%) had infected herds as opposed to only four (17%) for the 24 older settler households. This difference was not found to be statistically significant at the 5% level. One must consider the possibility that infection status could be related to herd

size, as new immigrants were found to own larger herds (see Chapters 2 and 3). In this study herd size was not found to be statistically significant, but herd size is in general a well-recognized risk factor for brucellosis.

8.4.2.6 Cattle herd size

Herd size was not found to be a significant risk factor for infection at the 5% level for the March or June surveys. From the March survey, all three positive herds were herds of 70 or more cattle. In June more larger herds were found to be infected than small herds, but this was not significant due to the low number of positive herds. This finding is in contrast to other studies that report higher seroprevalence in herds of larger size. (Boukary et al., 2013, Sanogo et al., 2012, Makita et al., 2011, Mohammed et al., 2011, Muma et al., 2007a, Ibrahim et al., 2010a, Al-Majali et al., 2009, Lindahl et al., 2014, Matope et al., 2011).

8.4.2.7 Clinical signs (AB, SB, WC)

Household heads were asked if their cattle had experienced abortions (AB), stillbirths (SB) or the birth of weak calves (WC) during the past year. Awareness of these clinical signs occurring over the last one year by the household head was assessed as a risk factor for the June survey. The difference in infection rate of herds reported to have clinical signs versus those that did not was not statistically significant at the 5% level (Table 92). This is in contrast to that of other authors reporting that animal seroprevalence is positively associated with abortion (Makita et al., 2011, Schelling et al., 2003, Ibrahim et al., 2010a, Lindahl et al., 2014).

Abortions in the KGR context are commonly reported, and abortion/stillbirths/weak calves are not clinical signs pathognomonic for brucellosis (see Chapter 9). Other infectious conditions such as trypanosomiasis, which has been reported to be prevalent in the KGR and the nearby area of the Jos Plateau (Majekodunmi et al., 2013, Santirso-Margaretto et al., 2014), have also been reported to cause abortions (Anene et al., 1991). Starvation and nutritional deficiencies, common problems during the dry season, are also likely to have an impact on the ability of gestating females to carry their young to term. The interpretation or recognition of these clinical signs by livestock keepers must be interpreted with care, as there may be

factors other than brucellosis contributing to the occurrence and observation of non-specific clinical signs. Two households infected with brucellosis did not report abortions. Under conditions of brucellosis endemicity, abortion storms are rare, and brucellosis may persist chronically in herds unnoticed by livestock keepers.

8.4.2.8 Owner perception of infection status

During the survey the heads of each household were questioned on experience of 'bakale' cases. In March 2011 they were asked to rank the disease of most importance in their herd. Of four herds that ranked brucellosis as the 'number one' disease of concern for their cattle, three were found to be FsRB positive (the only herds found to be positive overall). Other results contradict this finding: of the 27 households interviewed in March who claimed to have brucellosis in their cattle herd, only three were confirmed to have serological evidence of brucellosis (Table 88). However, none of the households claiming to be *Brucell*a-free were found to have serological positives. As brucellosis clinical signs (abortion, infertility, etc.) are not pathognomic for the disease and abortions are common, it is not surprising that more households report brucellosis than are serologically confirmed to have the disease. The evidence confirms that households are inaccurately assuming that all abortions are attributable to 'bakale'. Most household heads has good knowledge of the clinical signs of brucellosis and the mode of transmission, which may explain their ability to exclude brucellosis in the absence of obvious clinical signs such as abortion, hygroma etc.

From the survey in June 2011, positive brucellosis serological status was confirmed in four (25%) of the 16 herds declared by HHH as having brucellosis. Exactly the same percentage (25%) of brucellosis negative households were found to report brucellosis in their herd, demonstrating that HHH perception of brucellosis was not accurate in predicting positivity status (Table 92).

8.4.3 Prevalence and imperfect tests

The RBT is an imperfect test as it has a sensitivity and specificity <100%, and this has an impact on individual and herd prevalence. The extent of this impact in the context of low individual and herd prevalence as defined by the FsRB screening of cattle samples was explored. The individual true prevalence of cattle brucellosis was

estimated to be 0.4 and 0.3% for the March and June survey respectively, 0.1% lower than the apparent prevalence (which was calculated to be 0.6 and 0.5% respectively). One can be 95% confident that true individual prevalence of brucellosis in cattle in KGR lies between 0.1 and 0.9%. This re-emphasises the low burden of disease in this epidemiological context and raises questions about how the disease is maintained at such low levels. The lower confidence limit as calculated as per the method by Rogan-Gladen and Wilson was found to be 0 based on June survey data. This would suggest that there is a possibility that the KGR is free from brucellosis. Evidence unequivocally refuting this suggestion is the fact that *Brucella* was isolated from three cows, one sampled during the March survey and two sampled during the June survey. It is impossible for these three isolates to be contaminants as this organism is very fastidious and contamination with *Brucella* during bacteriological manipulation has never been reported. Hence *Brucella* is present in the KGR, albeit at low levels.

Calculation of PPV and NPV enable interpretation of the FsRB test results and an assessment of the likelihood of disease based on results obtained. For the context of the KGR where individual prevalence is very low, the proportion of cattle with a positive FsRB result that are truly brucellosis positive is between 60 and 66%. The proportion of cattle with negative FsRB results that are truly *Brucella*-free, however, was calculated to be 100%. This is because the RBT, in a context where vaccination is not practiced, is highly specific. Because a trade-off usually occurs between sensitivity and specificity, a highly specific test may be less sensitive, as is the case with the RBT (i.e. we are more likely to see few false positives but more false negatives). Overall, the RBT used in the low individual prevalence context of the KGR based on the assumptions of specificity and sensitivity specified by Greiner et al. (2009) is a useful test with high inference.

Values obtained for LR+ demonstrate that a positive RBT result is 491 times as likely to come from a cow with brucellosis as from one without the disease, which is a very high score. And vice versa, LR- values show that a negative result is only 0.02 times as likely to come from an animal with brucellosis as from an animal without the disease. Hence the test has high validity.

The RBT used under field conditions may have had a lower sensitivity and specificity than that reported by Greiner et al. (2009) (and thereby lower validity and inference) but in the absence of context specific values, the estimates derived from the Greiner et al. (2009) values are the only ones which can be calculated.

The issue of using 'imperfect tests' and the impact on herd prevalence was evaluated through calculation of aggregate sensitivity and specificity. Table 106 demonstrates that there is a very low probability of observing FsRB positives in disease-free herds. The highest probability would in fact be 15%. Hence it is possible that some of the herds classed as infected, such as 4001 where only one positive was detected out of 81 cattle sampled from a herd of 1500, may in fact be *Brucella* free. The maximum probability of missing an infected herd was found to be 11%, and his again was determined based on parameters for herd 4001. For most herds, however, the probability of missing an infected herd was well below 1%. The large probability of p_1 enables one to conclude that there is not enough evidence to conclude that the population is free from disease, and that it is very likely that the population is diseased. The small p_0 values suggest that it is very unlikely that the population is free from disease and is consistent with presence of disease in the population.

8.5 Conclusion

Brucella is present in cattle but there are few seropositives. This finding is in agreement with the claims of early researchers in Nigeria, who hypothesised that transhumant herds did not accumulate infection or transmit it from one animal to another (Banerjee and Bhatty, 1970, Anonymous, 1958, Esuruoso, 1974a, Eze, 1978). The evidence from KGR, however, goes against that of research in other transhumant pastoralist settings, which suggest that transmission is promoted in such systems (Macpherson, 1994, Omer et al., 2000, Boukary et al., 2013, Mai et al., 2013, Muma et al., 2006). It also disagrees with more recent publications from Nigeria, which claim that brucellosis prevalence is higher in the extensive than that the intensive systems (Mbuk et al., 2011, Farouk et al., 2013, Bertu et al., 2012, Maurice et al., 2013, Ocholi et al., 1996). Previously known risk factors for seropositivity in pastoralist systems were absent here. The few seropositive individual cattle and herds, however, do not permit firm conclusions to be drawn.

The picture for small ruminants and humans is one of low and nil seropositivity respectively. The zero prevalence in humans is paradoxical in a context where consumption of raw dairy products and intimate contact with livestock prevail. The reasons for this unexpected finding are unclear. The evidence from KGR raises some important questions about the epidemiology of brucellosis in this system and other systems with similar conditions:

- Why are there so few seropositives?
- Why is the prevalence of *Brucella* in cattle so low in the presence of *Brucella*?
- Why are there no human seropositives?
- Are the few sheep and goat seropositives infected with *B. abortus* as a result of spill-over from cattle or are they false positives?

This information is key to make recommendations about appropriate control measures. Fulani pastoralism is the dominant livestock production system in Nigeria and evidence from this study has wider relevance to extensive, pastoralist systems across Africa.

9 Chapter 9 Knowledge, perception and practices of relevance to brucellosis transmission in the KGR

9.1 Introduction

A qualitative approach is used to explore the social factors, including the knowledge, attitudes, behaviour and practices of KGR community members, which may play a role in the promotion or prevention of brucellosis transmission from animal to animal, and from animal to human. This novel multidisciplinary or systems approach enables the epidemiological disease situation to be interpreted within the wider context of pertinent social factors. In this chapter, knowledge, perception and practices of relevance to brucellosis presence and transmission in the KGR are explored. The Fulani refer to brucellosis as 'bakale' but despite this translation from fufulde having been pre-established by other authorities in the field, it is important to re-affirm onfirm the definition of this term according to KGR community perception.

Knowledge of KGR community members on animal disease, including symptoms, transmission and prevention was evaluated. The perception of household brucellosis status was also reviewed and compared to household status as determined by serological and bacteriological testing. The number of households who think they have animals affected by bakale is presented, as well as the symptoms reported and species thought to be infected. This is contrasted with reports of abortion, stillbirths and weak calves, and the relative contribution of brucellosis to overall reports is discussed. Practices relevant to animal-animal transmission are explored, including 1) household action once a case of brucellosis is recognised; 2) animal contact during grazing; 3) animal trading and 4) mating practices; and 5) practices surrounding parturition and abortion.

Community knowledge of zoonoses is reviewed, focusing on knowledge of human brucellosis symptoms, transmission and prevention. Household perception of human brucellosis status is also discussed. Practices pertinent to animal-human transmission are described including 1) milking; 2) milk processing; 3) milk consumption; 4) milk sale; 5) animal parturition and 6) slaughtering.

These 'social' or 'qualitative' factors are interpreted in the context of the epidemiological findings detailed in the previous chapter. The objective is to explore why individual prevalence of cattle brucellosis was found to be so low, in contrast with previous work on similar livestock production systems in Nigeria. Various hypotheses are put forward to explain the unexpected finding of zero human prevalence in a community with an animal reservoir.

9.2 Materials and methods

The assessment of social factors relevant to the presence and transmission of brucellosis in the KGR was based on the analysis of questionnaire data and topics discussed during focus group discussions (FGDs) with different groups of KGR community members. Questionnaires administered alongside the animal and/or human sampling during the three 2011 surveys (March, June and October) covered different themes - summarised in Table 107.

Theme (surveys)	*Knowledge of disease condition*	*Perception of HH status*	*AB/SB/ WC*	*Practices relevant to transmission*
Animal brucellosis & animal-animal transmission	Symptoms, transmission, prevention (M, O)	HH perception of disease status, symptoms reported, species affected (M, J, O)	HH status (J, O)	Grazing, mating and birthing practices, action in response to brucellosis case (M, J)
Human brucellosis & animal-human transmission	Symptoms, transmission, prevention (O)	HH perception of brucellosis HH and community cases (O)	NA	Milk consumption, milk processing, milk chain, animal birthing and slaughtering practices (M, J, O)

Table 107 Main themes covered by KAP section of the March, June and October questionnaires
(M- March, J- June, O- October, NA- not applicable)

Most themes were covered not only through administration of questionnaires at different time points and to different cohorts of households/individuals but also through application of a range of different participatory research methods. Triangulation was employed to validate the repeatability of data obtained and ensure better reliability of evidence. This method also ensured that variations in knowledge, perception and practices were captured. This was especially pertinent because, as

shown in Chapters 3, 4 and 5, KGR households, contrary to popular belief, are heterogeneous in socioeconomics terms.

Questionnaires were administered to households (HH) randomly selected during each survey (see Chapter 2). Data collected included 53 questionnaires for HH for the March survey, 40 questionnaires or HH for the June survey and 80 questionnaires or HH for the October survey. The 40 households questioned and sampled in October were the same as the 40 households sampled and questioned in June; questions on animal disease and animal transmission covered during the June survey were not re-administered to these 40 households to avoid duplication of information. The number of household answers given for different themes is not always the same as the total number of households sampled because some households chose not to respond to all questions and the number of answers obtained for each theme varies. The frequency of specific responses was always calculated as a proportion of the overall number of responses, enabling comparison between different responses.

During the October survey, each of the 1125 persons blood sampled were questioned relating to brucellosis risk behaviours, complementing the data gathered at household level; this included men and women of all age groups. Data was also collected on the age and sex of persons sampled that could be analysed for different age categories and sexes, to look for variations in exposure to risk factors across the groups.

The focus group discussions with different groups (including men and women) complemented the data gathered by the questionnaires. Most questionnaire respondents were household heads, or sons and brothers of the household head (see Chapter 4) and questionnaire data reflects the knowledge and perception of adult male patriarchs only. Household practices are dictated by the household head and can be assumed to reflect the practices of the household as a whole except perhaps milk processing, which as we will explore below, is the responsibility of women.

Qualitative data were derived from various focus group discussions (FGDs) (Table 108) and key informant interviews (KIIs) (Table 109). For details of how FGDs were conducted see Chapter 2. The first FGDs was undertaken in March 2011 on aspects of the milk chain with a woman's cooperative called the '*Rise of Dawn*'. This cooperative was formed '*to improve the lives of the KGR children and assist women*

in their trade'. The objective of the FGD undertaken with both men and women was to probe into the different stages between milking a cow and consuming its milk ('*from cow to mouth*') in order to learn more about the processing and consumption of dairy products in the KGR. FGDs were also conducted with butchers and traders to probe into practices surrounding selling and purchase of animals and slaughtering and butchering of meat in the KGR.

A KII was undertaken with the chairman of the *Lawol-Bote* cooperative called '*Road to success for dairy producers*', the aim of which is to promote the livelihoods of pastoralists. KII were also conducted with the veterinary and health services of KGR, including the medical doctor of a private clinic, the Area Veterinary Officer for the Kachia LGA and the KGR State Government Project Officer. The medical doctor runs the only clinic within the KGR, and as we will see in the next chapter, most human health problems of the KGR community are dealt with in his practice. He is the only medical doctor in the practice, the other staff comprising untrained auxiliary personnel moonlighting as pharmacists, nurses, cleaners and security guards. The clinic is equipped to deal with medical cases, surgical cases, and has a small ward for patients requiring hospitalisation. The Project Officer is an animal health technologist, whose main responsibilities include taking care of the administration of the reserve, overseeing reserve facilities (such as dams) and reporting disease outbreaks to the Area Veterinary Officer (AVO) in Kachia. The AVO was also interviewed; his remit is to lead a group of livestock technologists who deal with animal health issues in the Kachia LGA, which includes the KGR.

Target group	*Topic*	*No.*	*Sex*	*Age range (yrs)*	*Age (mean, median) (yrs)*	*Block of origin*
March						
Women's cooperative	Milk chain	8	F	20-60	NA	NA
October						
'From cow-to-mouth'	Milk chain	9	M	23-63	41.1, 40	2, 3, 4, 5, 6
		12	F	20-50	33.8, 32.5	1
Butchers	Slaughter and meat	12	M	17-45	32.5, 34	1
Traders	Sale and purchase	8	M	20-71	42, 37.5	1, 2, 4, 5

Table 108 Information on focus group discussions undertaken in KGR, including target group, topic, and number, sex, age and block of origin of participants

Target	*Description*	*Position*	*Sex*	*Age (yrs)*	*Length in post (yrs)*
June					
Dairy cooperative	Lawol-Bote Dairy producers, KGR	Chairman, pastoralist	Male	55	10
October					
Health services	Private clinic, KGR	Medical doctor	Male	65	13
Veterinary services	Kachia Local Government veterinary office	Area Veterinary Officer, Veterinarian	Male	52	10
Veterinary services	KGR Project office	Project Officer, animal health technologist	Male	35	2

Table 109 Information on key informant interviews undertaken in KGR, including position, age, sex and length in post of respondent

9.3 Results

9.3.1 Animal brucellosis and animal to animal transmission

9.3.1.1 Knowledge of general animal disease

9.3.1.1.1 Awareness of disease condition and symptoms

All but one of the questionnaire respondents from both March and October surveys had heard of animal bakale (Table 110) indicating that this is a common and well-known condition amongst Fulani herdsmen. To determine if the Fulani interpretation of the term 'bakale' correlates with the veterinary definition for 'brucellosis', respondents were asked to describe the symptoms and the species affected by 'bakale'. The most commonly cited symptoms, namely abortion, hygroma, infertile females, weak-born calves and stillbirths, were consistent with the clinical signs of brucellosis in animals, demonstrating that the Fulani interpretation of 'bakale' matches the western veterinary definition of 'brucellosis'. The most commonly cited symptom was abortion, followed by hygroma, infertility in females and finally weak-born calves/stillbirths (Figure 104). Clinical signs mentioned but which were not entirely consistent with classical signs of brucellosis included symptoms related to reproduction and parturition, namely, placental retention, premature calving, birth of small or deformed calves, vaginal discharge and low milk yield. One respondent mentioned that animals with bakale cannot move and another that the animals 'are weak', which was also mentioned during FGDs, and was explained to be due to the

lameness resulting from hygromas. Also along the same lines, one respondent described hindlimb swelling and swollen lymph nodes. Responses inconsistent with brucellosis symptoms included tarry and hard faeces, watery faeces and weight loss, but one or two households only mentioned these.

Findings from the March and October questionnaires are very similar, and demonstrate that approximately three quarters of households are aware that brucellosis causes abortion and around half are aware of hygromas. Some respondents provided detail of the joints affected by hygromas, the most common sites consisting of the carpus, stifle and hip. During the administration of one questionnaire, the household head took us to his herd to show us an example of a stifle hygroma (Figure 105), which was sampled for bacteriology. Carpal hygromas have been described as the more common manifestation of brucellosis joint effusion, but other forms of hygromas have also been reported and this is consistent with that observed by Fulani herdsmen (Ferney and Chantal, 1976).

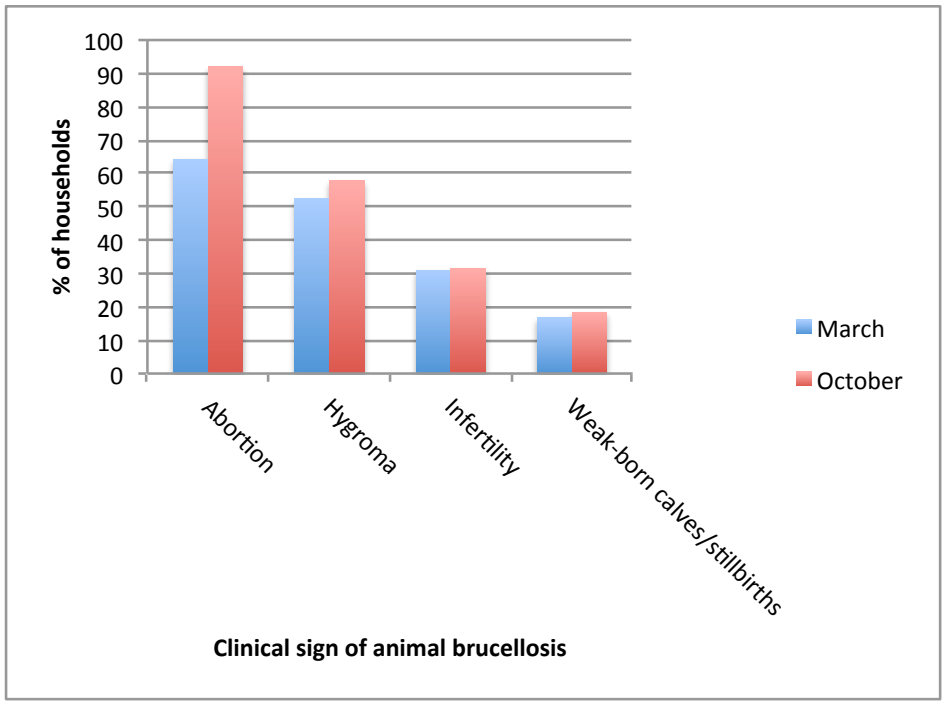


Figure 104 Percentage of households interviewed in March and October who mentioned abortion, hygroma, infertility in females and weakborn calves as clinical signs of brucellosis in animals

Figure 105 Stifle hygroma in a White Fulani cow

Survey	*Heard of bakale?*	
	N HH (Yes)	% HH (Yes)
March	54 (53)	98.1
October	39 (38)	97.4

Table 110 Number and percentage of questionnaire respondents that have heard of bakale

9.3.1.1.2 Transmission

Despite being familiar with the existence of brucellosis as a disease entity and its symptoms, the mode of transmission between cattle was less well known. Most respondents (73% in March and 50% in October surveys) had no knowledge of how brucellosis is transmitted. For the 27-50% that provided answers, transmission through males and mating was the most common response, followed by transmission via water, flies and mixing with other herds (Figure 106). Brucellosis was most often described as a 'sexually transmitted disease', passed to cows by infected bulls during mating. Some herdsmen were aware that transmission could occur through mating of household females with 'outside' or 'visiting' bulls. As one man put it: "*My cattle will catch bakale if a bull from a different herd comes into my herd*". Another respondent "*worried about bakale because all the neighbours' herds have bakale so I do not allow my males to mate with the neighbours' females and I don't allow my females to mate with the neighbours' males*".

This demonstrates awareness of transmission from males to females and vice versa. Transmission through contact with products of abortion or birthing materials was not mentioned, and this is an important gap in knowledge.

Transmission via water was described as occurring through contamination of drinking water with urine. A dam used as a drinking source was often referred to as a zone for transmission. The perception of water as mode of transmission is interesting because even though biologically incorrect, conditions for transmission through increased opportunity of contact with infected animals (including wildlife) around watering points has been described (Smits, 2013). A single respondent described flies as a mode of transmission. The confusion of bakale with trypanosomiasis, which can cause abortion, may explain this response. (Catley et al., 2012).

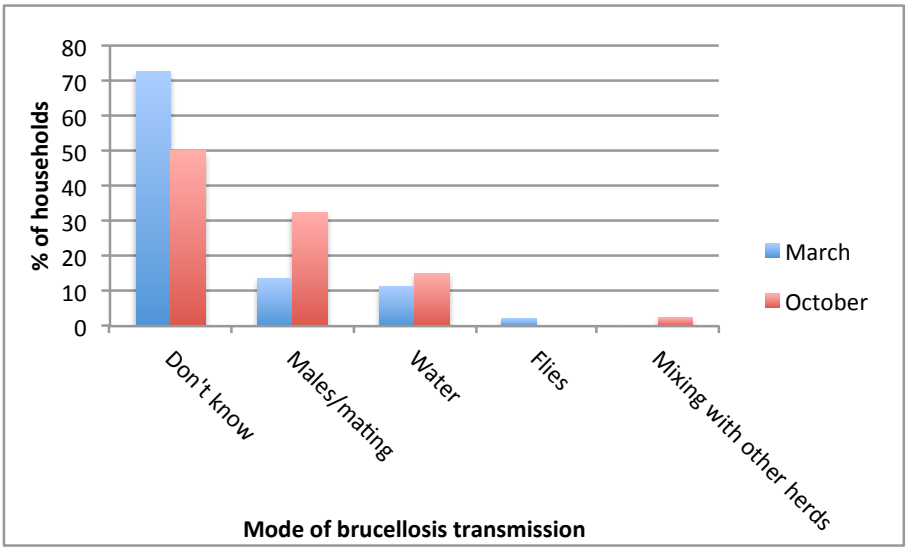


Figure 106 Percentage of times each mode of transmission was mentioned by respondents interviewed in March and October

9.3.1.1.3 Prevention

Though knowledge of brucellosis transmission was not consistently accurate, more respondents had clear ideas as to how to protect their herds from bakale (Figure 107). A third of respondents described the importance of each herd using its own bull: *"I avoid my females breeding with infected males; I avoid my bull mating in another herd; I avoid bulls from outside"* and even emphasised the importance of "*avoiding buying of bulls that have a history of the case"*.

Almost 20% of respondents described using herd biosecurity measures to prevent introduction of bakale into herds, including: "*Avoiding the migration routes followed by infected herds*" and "*preventing cattle from mixing with other animals, including both wild and domestic animals"*.

Herd biosecurity measures applied once a herd was infected were also mentioned: "*Isolation of infected bulls from the herd"; "selling of affected cows"* and "*separation of animals that have bakale from other animals in the herd*".

Respondents reported selling infected cows to get rid of bakale from their herd.

Six responents mentioned using vaccination as a preventative measure. The vaccine employed was the locally produced S19 vaccine. The use of a local vaccine and the manner in which the Fulani claimed to use it raises concerns. Firstly, one of quality control; analysis by (CITA) in Spain of the S19 vaccine produced at NVRI indicated that it did not provide a satisfactory number of colony forming units (CFU) per dose and showed smooth to rough dissociation. The vaccine may not stimulate an adequate immune response nor protect animals against wild *Brucella* strains. The second concern was that respondents indicated they "*vaccinate against brucellosis immediately after the animal is pregnant*". *Brucella* live vaccines may induce infection (milk excretion and abortions) if administered during pregnancy. This is of concern both as a risk of infection to animals, but also because of human infection with vaccine strains that are resistant to commonly used antibiotics (e.g. Rev 1 strains are resistant to streptomycin) (Grillo et al., 2006). However, given the poor quality of the local vaccine it is unlikely that vaccinating with this product would result in infection as the dose for immunisation and thereby infection is too low. Aspects of vaccination are discussed in more detail in Chapter 10.

Respondents complained about limited availability of the vaccine, and claimed to use "*local herbs when the vaccine is unavailable"*. Traditional herbs, used alone or in combination with veterinary drugs, mostly antibiotics such as 'LA' (long acting oxytetracycline or penicillin) were mentioned as the preventive method of choice when the vaccine was unavailable or as an alternative to the vaccine. The use of herbs was described as a longstanding practice a tradition passed from father to son: "O*ur father used to prepare some herbs and we have learned this from him"*.

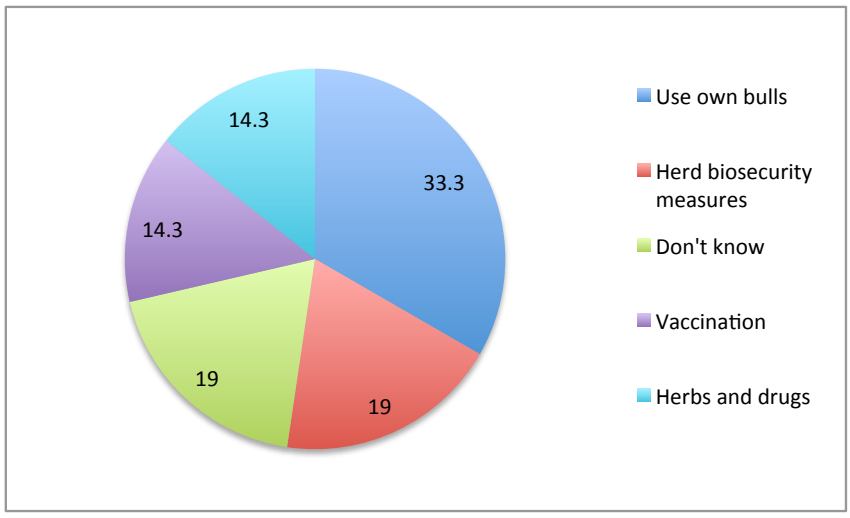


Figure 107 Percentage of times each mode of brucellosis prevention mentioned by respondents interviewed during October survey

9.3.1.2 Perception of household animal brucellosis status

9.3.1.2.1 Number of households who think they have bakale

Between three quarters and half of households, depending on the survey, believed they had animals infected with bakale. No statistically significant association was found between the serological infection status of cattle (or other species) in a household and the respondent perception of bakale household status (see Chapter 8). In the March survey, priority ranking of household cattle diseases indicated that livestock keepers with serological and bacteriological evidence of infection consistently ranked bakale as the number one problem in their herd.

The high number of HH claiming to be suffering from animal bakale shows the perception of bakale as a widespread and pertinent issue for the KGR community. The results are in agreement with FGDs undertaken during pre-sampling pilot studies that emphasised KGR community concern of bakale in their animals and people.

The lack of agreement between perceived infection status and serological status can be interpreted in two ways: (i) Fulani are erroneously assuming bakale presence in their herd due to occurrence of abortions and other manifestations, caused by another aetiological agent (ii) Fulani are referring to 'historical' herd infections, which can no longer be detected immunologically. Eight respondents mentioned past experiences of bakale: *"My animals had bakale 8 years ago; I had experience of*

bakale a few years back; I have not suffered from bakale for several years; 'Since I have moved to the KGR 17 years ago I have not noticed bakale in my herd; Some years back I did have a bakale problem but now it has gone".

None of the herds of the HH describing these past cases of bakale were found to have serological evidence of infection. This raises questions about the 'infected herds' and the potential for the disease to 'die-out' in this system. Longitudinal studies monitoring herd serological status over time would be needed to investigate further.

9.3.1.2.2 Symptoms reported and species thought to be affected

Bakale is perceived to only affect cattle (Figure 108). This perception fits the serological evidence. Respondents stated that sheep and goats abort, but they do not refer to small ruminant abortions as bakale. Bakale, as a term is not synonymous with abortion, but rather corresponds to a specific disease condition affecting a specific species with a specific range of symptoms. The Fulani perception and description of the disease mirrors the epidemiological findings.

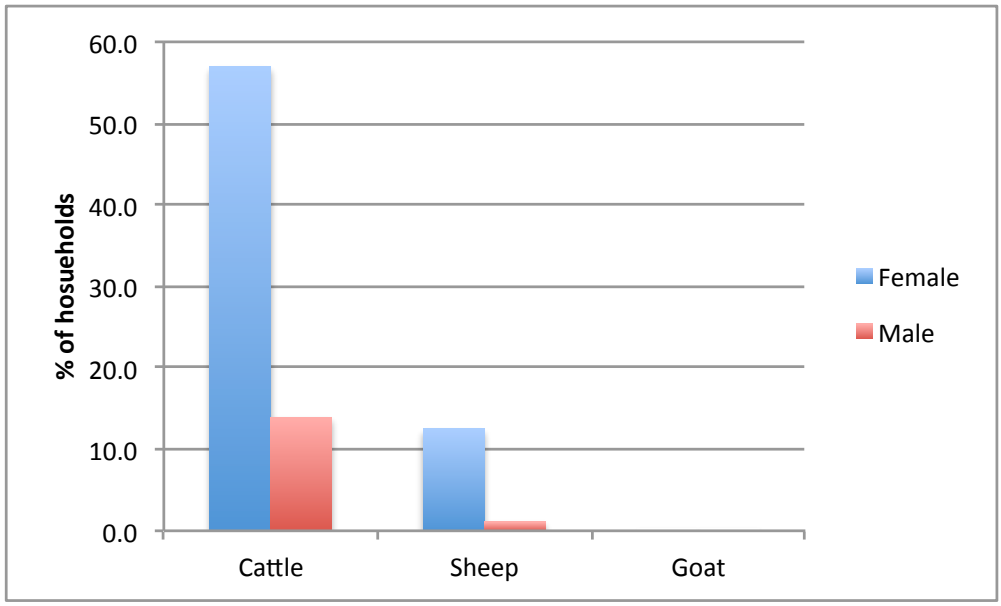


Figure 108 Percentage of households interviewed in March and October that report brucellosis cases in each respective species and sex

When asked to define the symptoms, specific species and sex of the animal affected by bakale, the responses agree with those previously described. Abortion, hygroma and infertility were the top three clinical signs mentioned (Figure 109). Signs

associated with reproductive status are perceived to apply to female cattle, few males were reported to have bakale with the only symptom being the presence of hygroma.

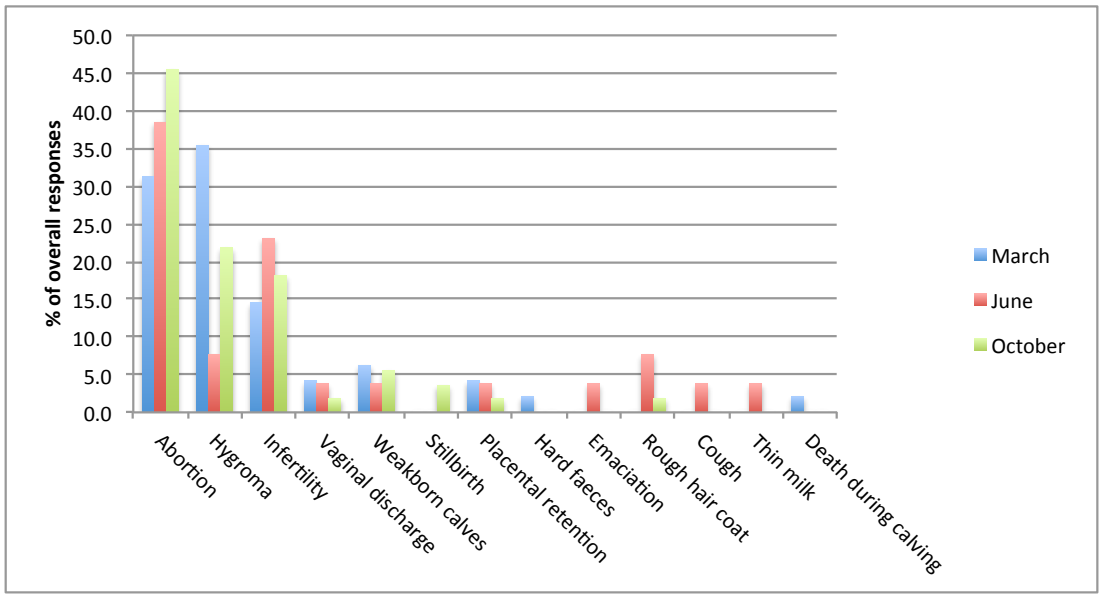


Figure 109 Percentage number of times specific brucellosis clinical signs mentioned by respondents interviewed in March, June and October when asked to list symptoms of brucellosis in cattle

9.3.1.2.3 Brucellosis perception of local veterinary services

The AVO reported complaints of brucellosis in the Kachia Local Government Area with reports of (mostly) abortions and hygromas in cattle. Cases were mostly diagnosed on clinical suspicion of the disease (diagnostic capacity was poor). The AVO complained that administrative commitments prevented him to attend to cases, leading to delegation of diagnosis to animal health technologists. His concern was that due to the insufficient training, paravets are not qualified to make good recommendations about animal health. An example is the fact that treatment for brucellosis cases by the local veterinary services in the Kachia LGA is sulphadimidine. Administration of a single dose of antibiotic will not cure brucellosis. Animal health technologists report that in their experience, Fulani herders claim that prompt treatment with antibiotics is effective. This false impression may be due to the fact that cows only gestate every four years in this production system and only have an opportunity to abort every half-decade.

When quizzed on the relative importance of brucellosis in Kachia LGA, the AVO prioritised brucellosis at number 4 or 5, with trypanosomiasis and fluke being top of the list. Perceptions of health problems in the KGR is discussed in Chapter 11.

The Project Officer of the KGR (an animal health technologist) echoed the perceptions of the AVO. He described a series of complaints to the project office about abortion. He recognised swelling of joints as a symptom of brucellosis. In one month, he reported an average of 30-40 complaints of bakale. Some complaints came from within KGR, and others from Fulani living outside the grazing reserve. He reported personally going to investigate an abortion storm two years previously, when about 20 cows had aborted. The AVO was called in to take samples for laboratory confirmation, as the client was the owner of a commercial farm. The laboratory results apparently confirmed a brucellosis outbreak. When questioned about treatment and prevention, the PO described his treatment of choice as sulphadimidine and he confirmed that there were no government-led control measures currently in place for brucellosis in Nigeria. The PO mentioned that the Fulani had their own biosecurity measures, stating: "*If the Fulani know their neighbour has a case of bakale, they take their cattle away from the area as they know their own may be affected"*.

In terms of species affected, the PO's perception was that *'the Fulani just worry about bakale in cattle, not sheep and goats'*, which is in keeping with the view expressed by the KGR community.

9.3.1.3 Reports of abortions, stillbirths, weak calves and hygromas

Respondents were asked to enumerate the number of abortions, stillbirths, birth of weak calves and hygromas experienced in their herd in the previous one year (between June 2010 and June 2011 for the June survey and October 2010 and October 2011 for October survey) and in the previous four years (June 2007 to June 2010 for June survey). Respondents were also asked the pregnancy number of the abortion/stillbirth/weak calf event (Table 111). Recall of events beyond a one-year period was very poor and such data were discounted.

More abortions (average of 1.7 per household) than any other symptom were observed. The parity at which these abortions occur is equal across 1st, 2nd and 3rd

pregnancies. Brucellosis most commonly causes abortions during first pregnancy so this finding suggests that other infections agents and/or factors are responsible for abortions in this system. Poor nutritional status during gestation and other conditions such as trypanosomiasis are potential alternative causes of abortion. The 1.7 abortions and 1.3 stillbirths per household correspond to the loss of 3 calves per household per year for 50% of households that reported these symptoms - a considerable impact on productivity.

	Abortion		*Stillbirth*		*Birth Weak calf*		*Hygroma*
June	**1yr**	**3yr**	**1yr**	**3yr**	**1yr**	**3yr**	
N HH (Yes)	40 (21)	40 (17)	40 (9)	40 (5)	40 (20)	40 (8)	
% HH (Yes)	52.5	42.5	22.5	12.5	50.0	20.0	
N HH (?)	40 (0)	40 (9)	40 (0)	40 (11)	40 (0)	40 (11)	
N cows (1st preg)	11	4	5	1	10	3	
N cows (2nd preg)	10	4	4	1	8	0	
N cows (3rd preg)	10	5	2	1	5	0	
N cows (≥ 4th preg)	4	3	1	1	9	1	
Total N cows	**35**	**16**	**12**	**4**	**22**	**4**	
N cows/HH/yr	**1.7**	**0.3**	**1.3**	**0.3**	**1.1**	**0.2**	
October	**1yr**		**1yr**		**1yr**		**1yr**
N HH (Yes)	41 (22)		41 (12)		41 (21)		41 (13)
% HH (Yes)	53.7		29.3		51.2		31.7

Table 111 Number and percentage of households interviewed in June and October reporting abortions, stillbirths, birth of weak calves and hygromas over previous one or three years; number of cows for which abortion has occurred during, 1st, 2nd, 3rd or ≥ 4th pregnancy

The number of abortions, stillbirths and birth of weak calves were divided by the total herd size to define the rate of each 'event' for each household, both for the June and October survey (Figure 110). Both surveys show that most households do not report having experienced these symptoms. The remaining households have a rate of abortion/stillbirth/birth of weak calf of five per cent or less, which represents a considerable impact on their herd productivity.

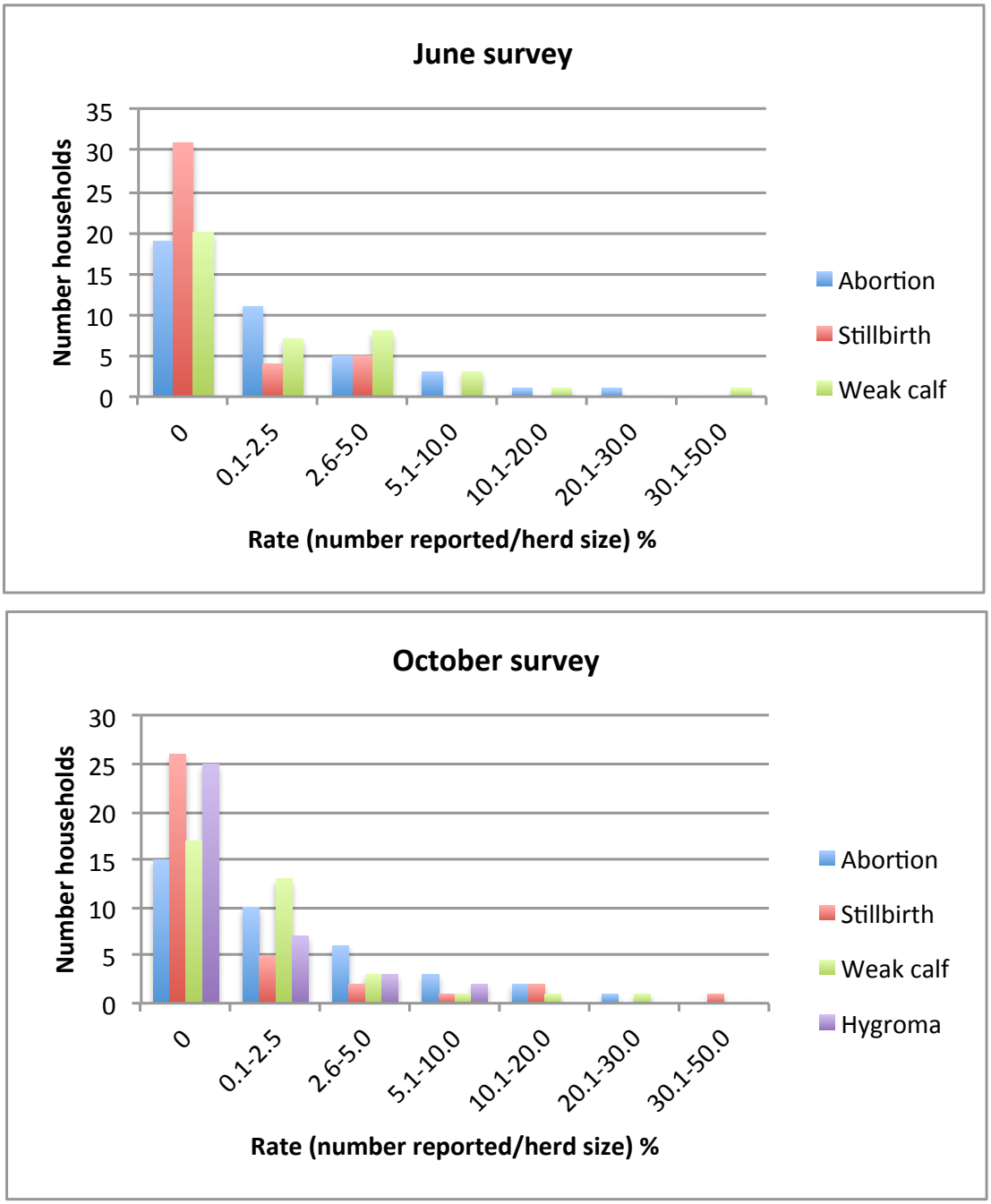


Figure 110 Frequency of households with a range of rates of abortion, stillbirth, weak calves and hygromas over a one-year period for the June survey (top panel) and October survey (bottom panel)

9.3.1.4 Practices relevant to animal-animal transmission

9.3.1.4.1 HH action once they recognise a case of brucellosis in their animals

Respondent knowledge of strategies to prevent brucellosis from being introduced into a herd was reviewed in 9.3.1.1.3 Prevention. This is contrasted here with what

households actually did when they suspected case of brucellosis in their cattle. Households mostly administer veterinary drugs to treat cases, although herbs are also used (Figure 111, Figure 112). Selling animals, branding of hygromas, seeking veterinary advice and vaccination were also mentioned as strategies to deal with infected cattle. Figure 112 shows that the most common drugs administered were antibiotics, followed by veterinary drugs of unknown type (including some procured from NVRI). Some people reported treating with trypanocides and de-wormers. The type of antibiotic administered was an agent referred to as 'LA', a long-acting broad-spectrum antibiotic such as oxytetracycline or penicillin. Other antibiotics used include sulfadimidine and tylosin. The use of broad-spectrum antibiotics is a waste of money that will fail to resolve brucellosis problems and also raises concerns about antibiotic-resistance. This antibiotic regime is the one recommended by animal health technologists, and it is unsurprising that Fulani report using this treatment.

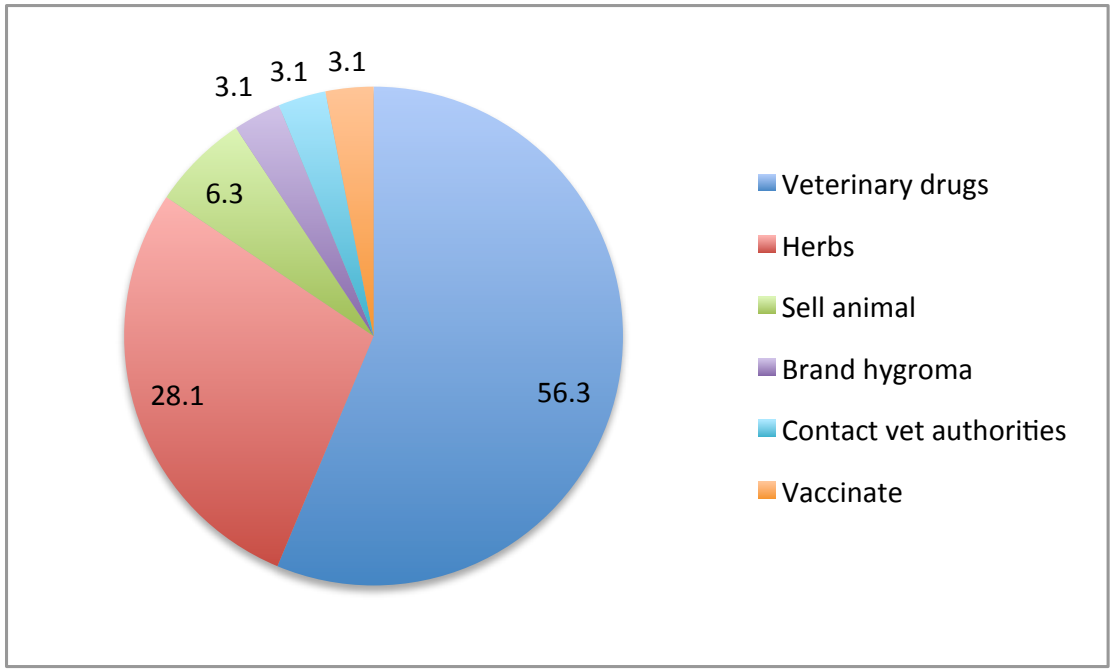


Figure 111 Percentage of times a mode of action mentioned in response to what householders do when a case of brucellosis is recognised in cattle in their household, October survey

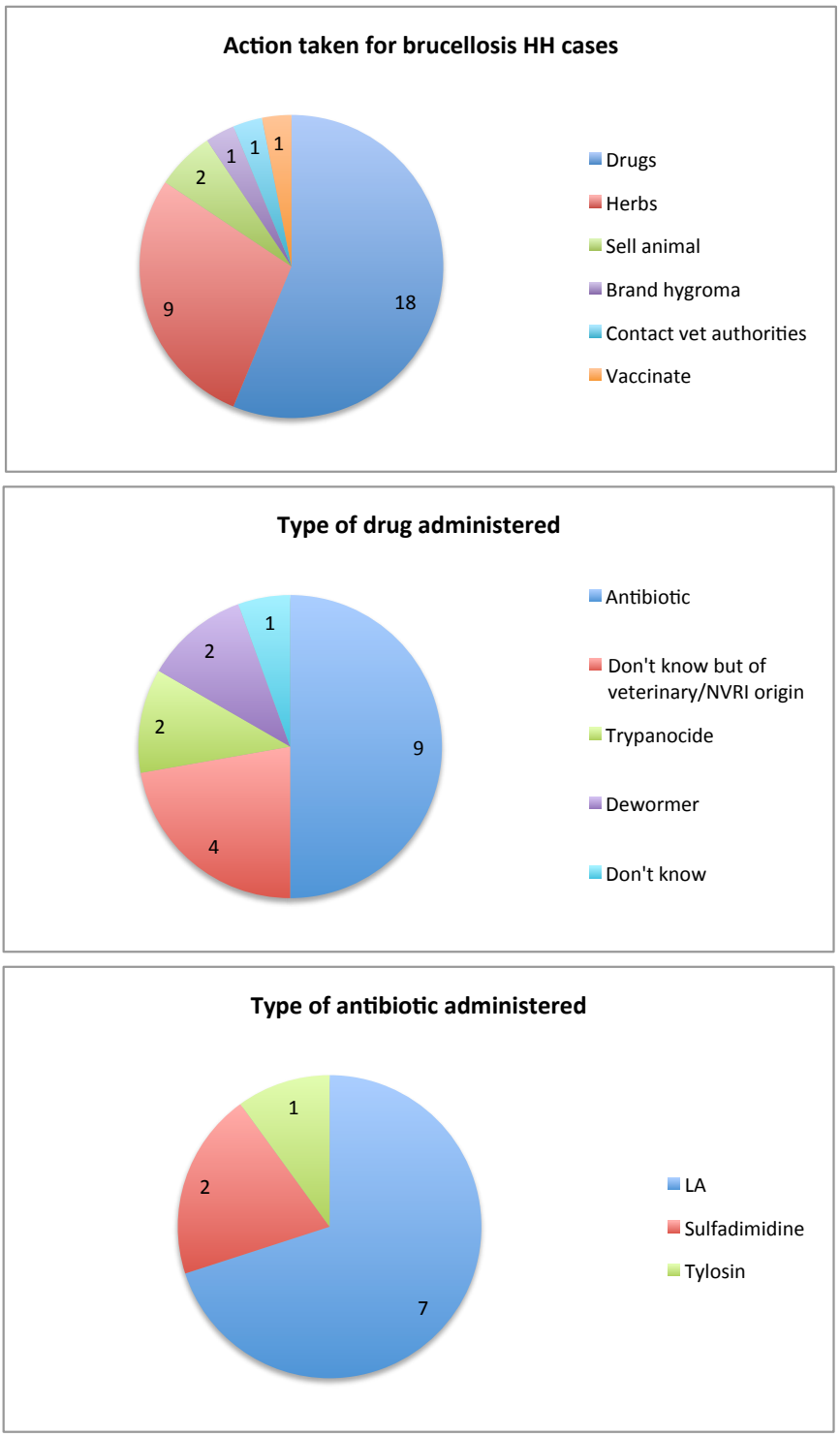


Figure 112 Number of times response mentioned for action taken against brucellosis case in cattle (top panel), type of drug used (middle panel) and type of antibiotic administered (lower panel), October survey

(NB/ number of responses in related categories may not always tally because more than one response may have been given per household)

9.3.1.4.2 Grazing and mating practices

Even though some households exercise some level of biosecurity and minimise contact with other herds, over 90% of respondents claimed that they engage in common grazing (Table 112). Respondents explained that *"because we live in the same place, we go grazing together"*, and used the same areas of pasture, mostly in fadama areas, because there are no *"demarcations"* or "*exclusive grazing yards"*. A common response was *"everyone in the KGR had equal rights to grazing and the grazing reserve; everyone has equal ownership of the KGR"*. Even though the Fulani do not legally own the land in the grazing reserve, they perceive it as belonging to the community as a whole, and land use is divided equally between them (see Chapter 3). A number of people also used *"we move more freely here"*, emphasising the emancipation felt by people living in the grazing reserve as opposed perhaps to those Fulani living in close contact with ethnic groups engaging in conflicting livelihoods such as crop farming.

Although different households use the same area of land, the respondents stressed that each herd had its own herd boy and: *"The land is huge but you can meet people on the way to where you are going but a conscious effort is made to graze away from other herds for disease prevention purposes"*.

Nearly 70% of respondents confirmed cattle contact with wildlife (Table 112). The most common species mentioned were monkeys, followed by antelopes (Figure 113). Antelopes may be reservoir of *Brucella* infection, and should that be the case, elimination of brucellosis in the livestock reservoir, without addressing the issue of a wildlife reservoir, could result in re-emergence of disease in livestock. The role of wildlife in brucellosis transmission is speculative in the absence of epidemiological data.

Only 25-30% of respondents reported actively encouraging mating of household females with males of other herds and vice versa; the majority of respondents actively prevent inter-herd mixing of males and females (Figure 114 and Figure 115). The reasons given for allowing HH females from mating with males of other herds included improvement of herd genetics (including crossbreeding of Bunaji with Rahaji cattle, giving the prized red/white offspring). This was also mentioned as the

only way in which herds that do not own a bull can mate their females. The reasons given for loaning males to other herds were: *"To assist each other in our livestock farming; to assist neighbours that don't have a breeding bull; because you have to allow other herds to benefit from yours."*

"Fear of brucellosis" was the main reason for not allowing outside males or females to mate with animals within the herd. One respondent said: *"If a request for one of my bulls is made, I agree but I do not take the animal into my herd again. I sell him to the person or I take it to market"*.

This option is only feasible for individuals with large herds but shows awareness of bakale transmission from mating. Some respondents stated that they discouraged mating with other herds because they wanted to *"maintain their own cattle type"*.

A KII with the chairman of the Dairy cooperative revealed that the cooperative obtained five Friesian bulls in 2007 from the 'Integrated Dairy (WAMCO) Farm' in Vom (part of the Nigerian Veterinary Research Institute, near Jos) to cross with White Fulani (Bunaji) cattle in the KGR:*"The cooperative owns the bulls and if members have heifers on heat they can be brought to the bull for mating"*. The KGR Chairman kept the bulls in his herd, but said only one Friesian bull remained (four had died). He reported that the Friesian crossbreed progeny needed more food, were more prone to death if sick and did not give much more milk than the White Fulani.

The Chairmans herd was randomly selected for sampling during the June survey, and his Friesian bull was one of the males found positive. Colleagues at NVRI sampled 187 cattle at the WAMCO farm in April 2012, and found 24 positive using the standard RBT (CITA antigen), a seroprevalence of 12.8% (8.4-18.5%, Fisher's 95% CI). Brucellosis may have been introduced into the chairman's herd (and KGR) from the infected Friesian bull, or the bulls may have been *Brucella* free on introduction into KGR and became infected by mating with infected KGR females.

Practice	*N HH (Yes)*	*% HH Yes*
Common grazing with other herds	40 (37)	92.5
Contact with wildlife during grazing or drinking	40 (27)	67.5
Mating of HH females with males of other herds	40 (10)	25.0
Mating of HH males with females of other herds	40 (12)	30.0

Table 112 Number and % of HH who engage in specific grazing and mating practices, June

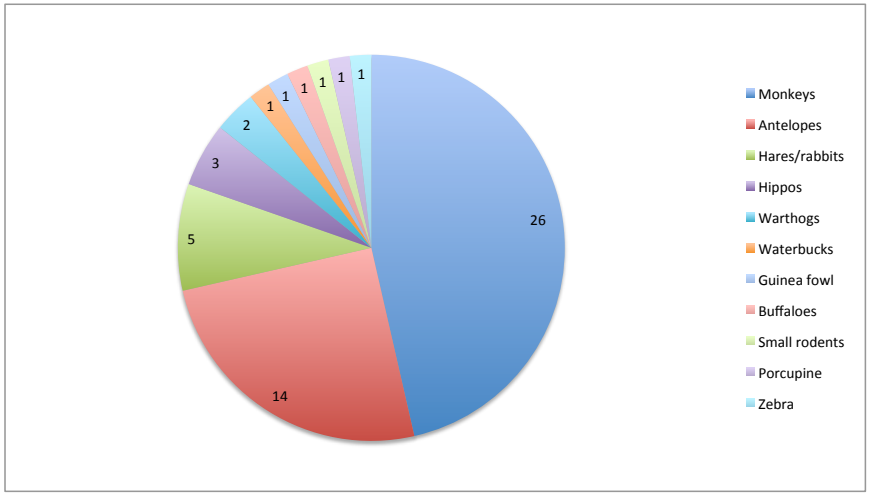


Figure 113 Number of times each wildlife species mentioned in answer to question 'Do your cattle share grazing or watering points with wildlife, and if so, what type?', June survey

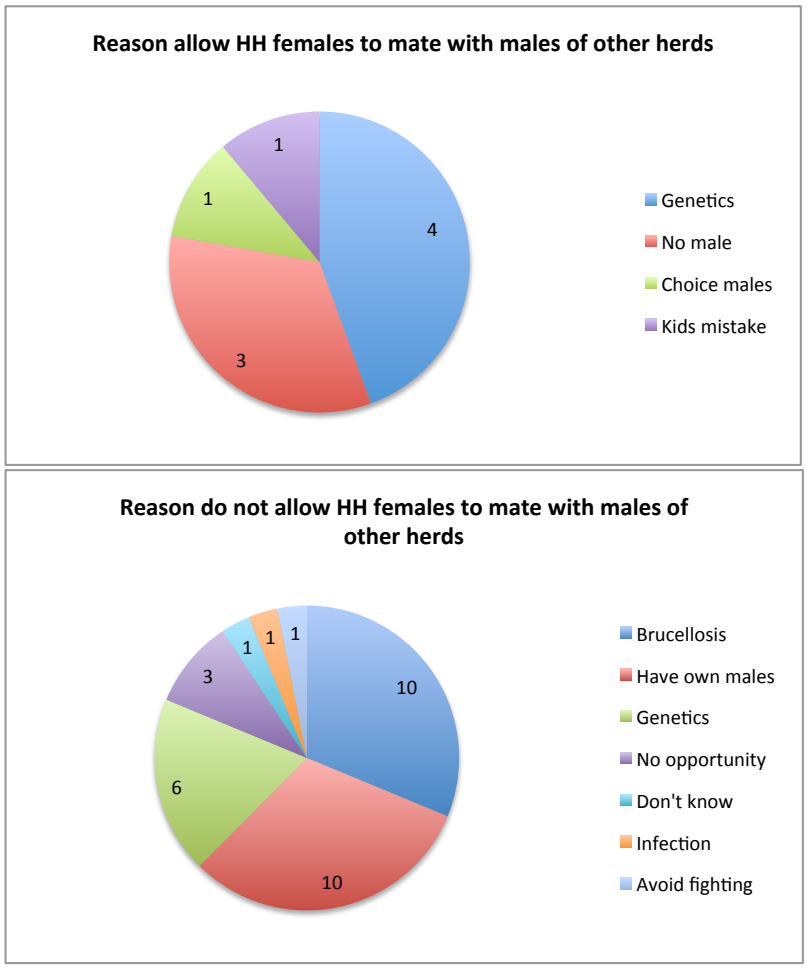


Figure 114 Frequency of reasons given for allowing (top panel) or not allowing (bottom panel) HH females to mate with males of other herds, June survey

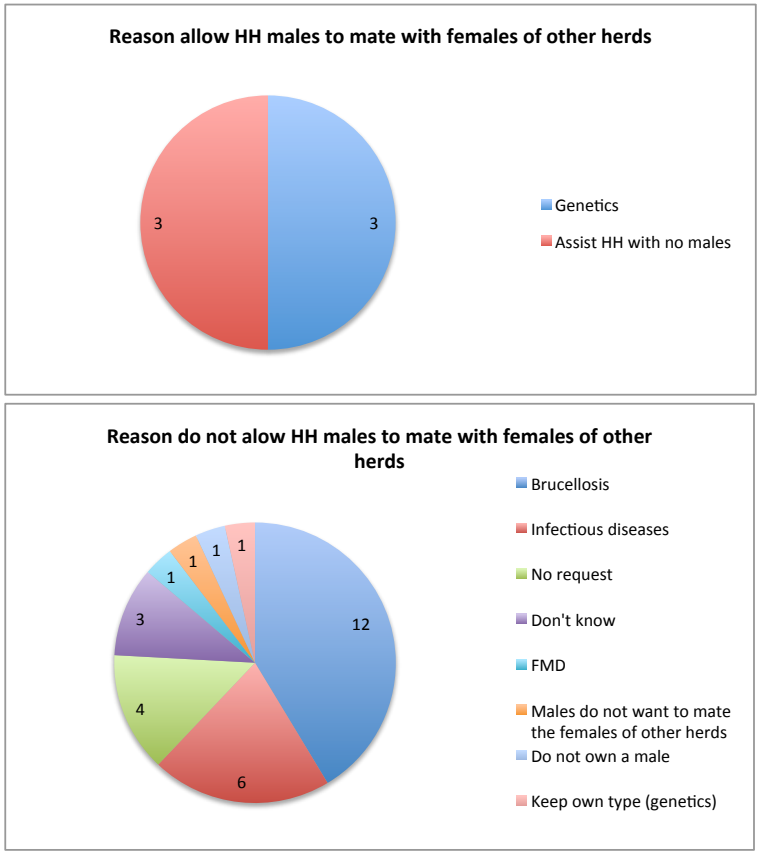


Figure 115 Frequency of reasons given for allowing (top panel) or not allowing (bottom panel) HH males to mate with females of other herds, June survey

9.3.1.4.3 Practices surrounding birthing and abortions

Animal to animal transmission occurs mainly through contact with birthing materials or abortion products. Respondents were asked if/how they disposed of products of abortion and birthing materials. Most reported discarding birthing materials (Figure 116). Two described leaving abortion products in the field for fear of catching the disease through contact with the material (see 9.3.2.3.2). Respondents described disposing of birthing materials or abortion products far from the homestead to prevent access by other animals in the herd. Materials were also reported fed to dogs or vultures (promoting transmission to these species). *B. abortus* infection has been reported in dogs in Nigeria (Osinubi et al., 2005, Cadmus et al., 2011). Dogs are sentinels of brucellosis and could be screened to give an indication of infection status of a herd status. Not all households keep dogs but it is much cheaper to sample one dog than a whole herd of cattle. Dog sampling was attempted but abandoned in this study as were unable to catch and restrain their dogs.

Parturition in cows was reported to take place away from herd in over 80% of households (Figure 116). Most herders give their cattle the freedom to step away from the herd during parturition: *"The animal steps away from the rest; the animal finds a solitary place away from the herd"*. Isolation during parturition is a natural instinct and is a good strategy to prevent transmission of *Brucella*. Intensive farming is a barrier to natural isolation, promoting conditions for transmission.

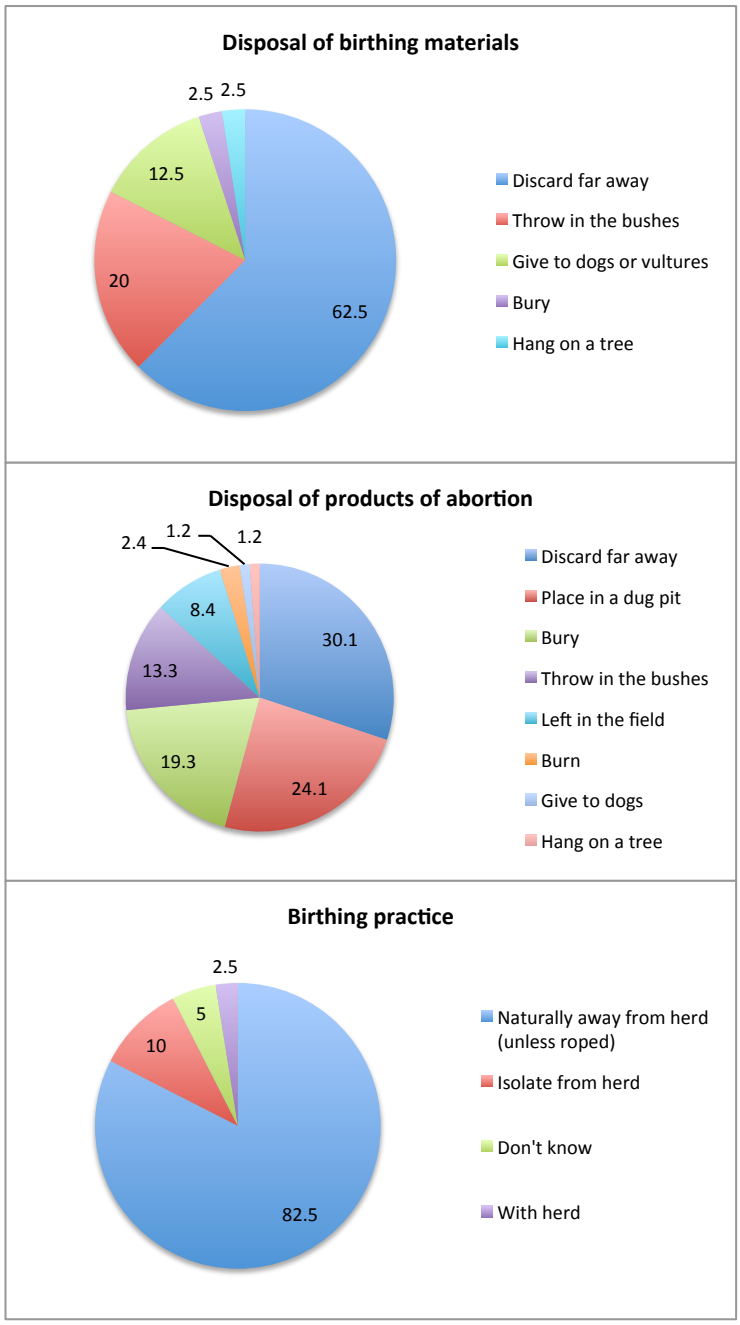


Figure 116 Percentage of respondents who dispose of birthing materials or products of abortion in a specific way and report a specific birthing practice, June and March survey

9.3.1.4.4 Practices surrounding cattle purchase, sale and management

FGDs with traders confirmed that livestock keepers are more likely to sell animals which they want to 'dispose of', including cattle with bakale. These animals are sold at four main livestock markets: Kasuna Magani, 80km away; Mariri (Saminaka), 120km away; Kaduna 100km away and Abuja 200 km away. After the animals are sold they are *"transported from the market to slaughterhouses down south or sold to other traders who then sell them to other pastoralists"*. Animals are moved from north to south to meet the high demand for meat down south. This has significance from the perspective of animal-to-animal transmission, as close contact of animals from multiple areas of origin at these markets creates the perfect opportunities for transmission, and perhaps explains why the prevalence of brucellosis in trade animals is so high in studies undertaken at large abattoirs in the south (Cadmus et al., 2013, Cadmus et al., 2009, Cadmus et al., 2008, Cadmus et al., 2006, Cadmus et al., 2010, Ishola and Ogundipe, 2000, Ogundipe et al., 1994, Chukwu, 1987), and also why the human prevalence in these abattoirs is also found to be so significant (Alausa and Awoseyi, 1975, Alausa, 1979a, Brisibe et al., 1993, Useh et al., 1996, Cadmus et al., 2006, Gusi et al., 2010).

Traders are also involved in sourcing of animals from the four main markets at the request of animal keepers in the KGR. Both males and females are purchased, mostly of the White Fulani breed. Exotic breeds were explained *"not to be sold at livestock markets because they die"*. These breeds, are sold at established specialised intensive farms. In general, traders did not know where animals purchased originated from, but confirmed: *"They are not from Niger as those cattle go straight down to Lagos for slaughter at the big urban abattoirs so they are from Nigeria"*.

The disease status of animals is not generally considered as a criterion on which to base selection of animals for purchase, as the traders state they *"just go for good looking animals*". Introduction of animals from livestock markets could be an important source of brucellosis for the KGR.

Sale and purchase of animals also takes place through direct trade between KGR community members, who reported having a good awareness of bakale infected herds and do not purchase cattle from herds known to be infected.

9.3.2 Human brucellosis and animal to human transmission

9.3.2.1 Knowledge of brucellosis in people

9.3.2.1.1 Awareness of disease condition and symptoms

Fewer than 50% of persons interviewed were aware that brucellosis affects humans (Figure 117). The symptoms described by those households that had heard of the disease were mostly transposed from the symptoms described in cattle, namely abortion, infertility in women, stillbirth etc. A minority of respondents accurately recognised brucellosis symptoms as fever (eight responses), body and joint pains (six responses), headaches, tiredness and orchitis.

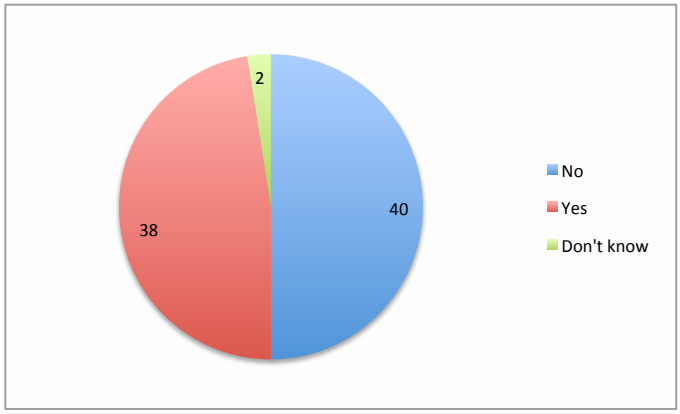


Figure 117 Frequency of responses to 'Do you know of a disease called brucellosis in people?'

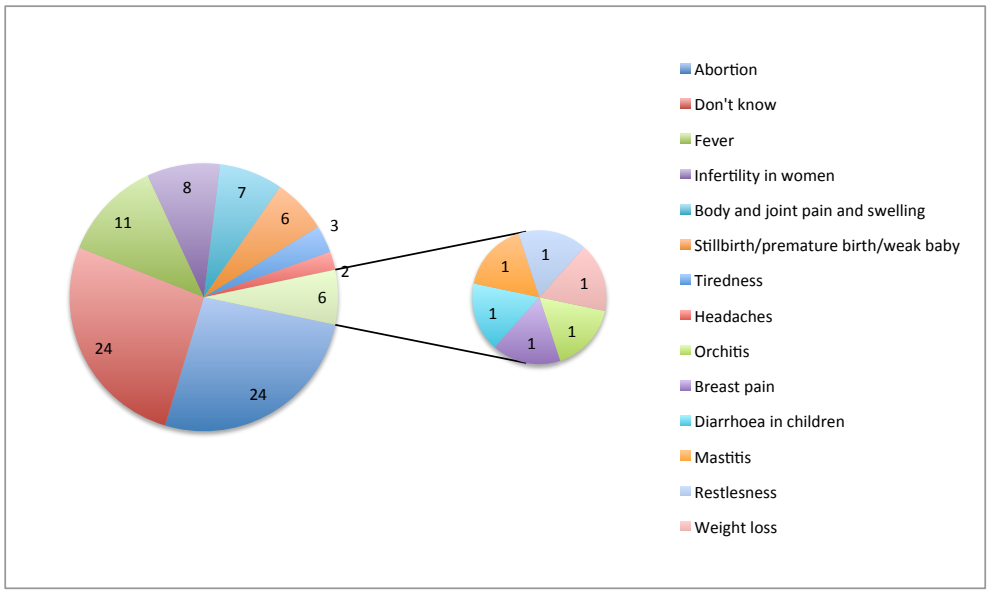


Figure 118 Frequency of responses to 'What are the symptoms of brucellosis in people?'

9.3.2.1.2 Transmission of human brucellosis

Knowledge of mode of transmission was poor, with 68 respondents claiming to have no awareness of how humans become infected (Figure 119). Only one interviewee reported awareness of catching brucellosis from drinking infected milk, and another from *"general contact with the place where animals are kept"*. Transposing knowledge of animal-to-animal transmission led to responses such as "*contact with the urine of infected cows"* and *"infidelity or sexual contact"*. Awareness of transmission through the consumption of raw milk or through contact with products of abortion or birthing materials was almost non-existent.

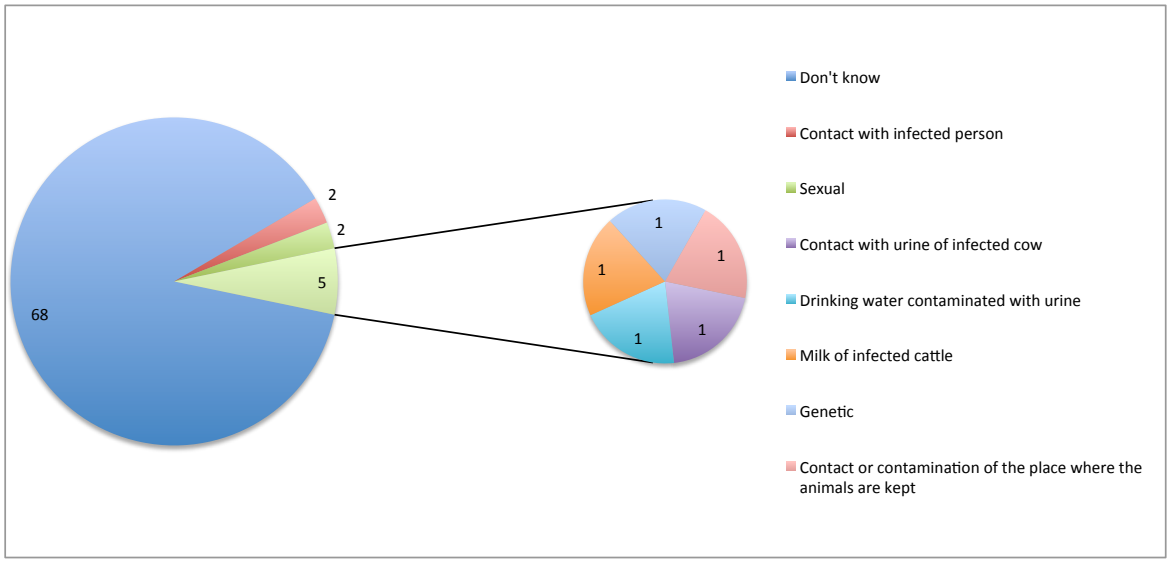


Figure 119 Frequency of responses given to 'How do people catch brucellosis?', October survey

9.3.2.1.3 Prevention of human brucellosis

Knowledge of how people can prevent themselves from catching brucellosis was poor, with 61 respondents answering 'don't know' (Figure 120). Only six respondents were aware of strategies for preventing animal-to-human transmission, including *"boiling of milk; disposing of aborted foetus; treating infected animals early and getting drugs for the animals so they can be treated"*.

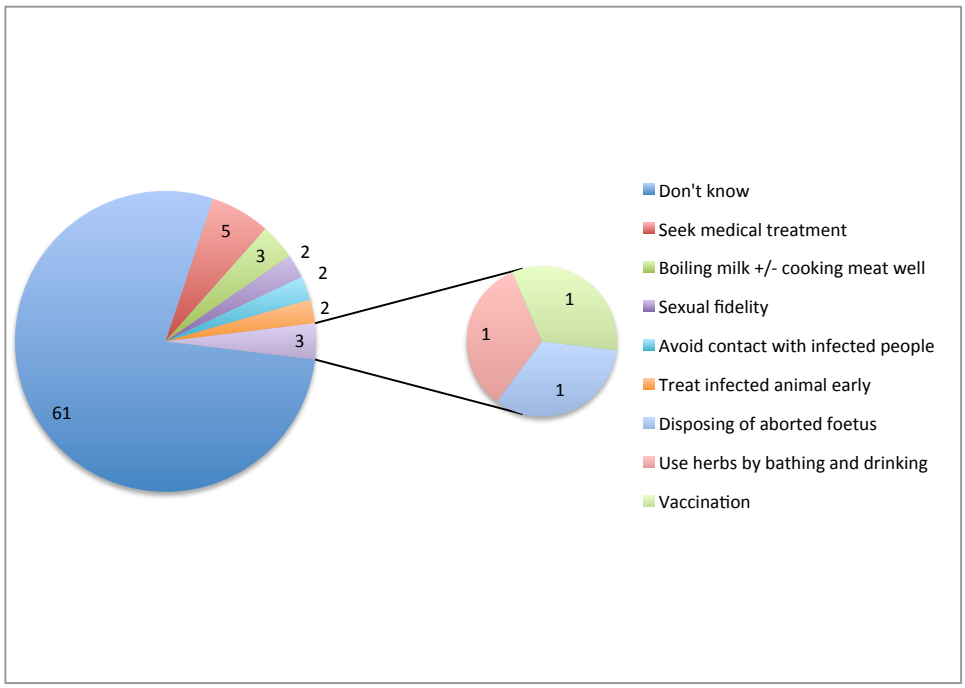


Figure 120 Frequency of responses given to question 'What can people do to stop themselves catching brucellosis?', October survey

9.3.2.1.4 Knowledge of zoonoses

General knowledge of zoonoses was evaluated by asking respondents if they were aware of any disease conditions that people can catch from their cattle. A minority answered yes to this (Figure 121). Knowledge of zoonoses among butchers was also evaluated during a FGD; butchers claimed they were not aware of such diseases.

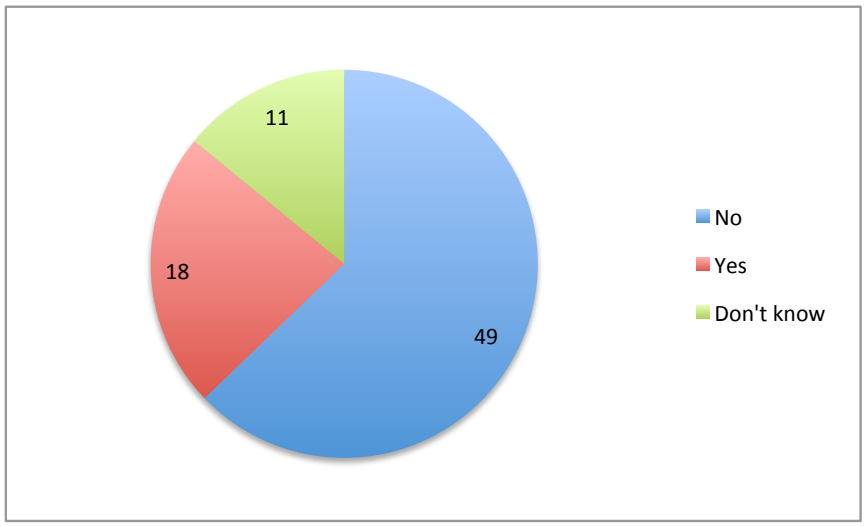


Figure 121 Frequency of responses to 'Can you think of any disease which people can catch from their cattle?', October survey

The 18 respondents who answered yes were asked to give the local names of the diseases (Figure 122), to describe the symptoms of the disease in people and animals, and to describe what people can do to protect themselves from catching these diseases (Table 113). Brucellosis was the most highly cited zoonosis, however sensitisation to this condition through previous questioning may have resulted in respondent bias. Malaria (jonte) was thought to be a zoonosis by some, as well as FMD (boru), anthrax (sefa) bovine TB (tarin puka) and *Fasciola gigantica* (malewama-hanta). 'Hanta' is discussed in more detail in Chapter 11. One condition, 'fuka' was mentioned but was not translated and symptoms were not described.

A common feature of persons able to identify brucellosis, anthrax and bovine TB as zoonoses was reporting of having listened to a radio show broadcast by NVRI on *"how one can contract disease from animals and animal products"*. This finding demonstrates the usefulness of using radio as a messaging tool.

One respondent stated: *"our father used to tell us not to drink raw milk because of bakale"*, which shows the wisdom of community elders and the tradition of passing on knowledge from father to son in Fulani culture.

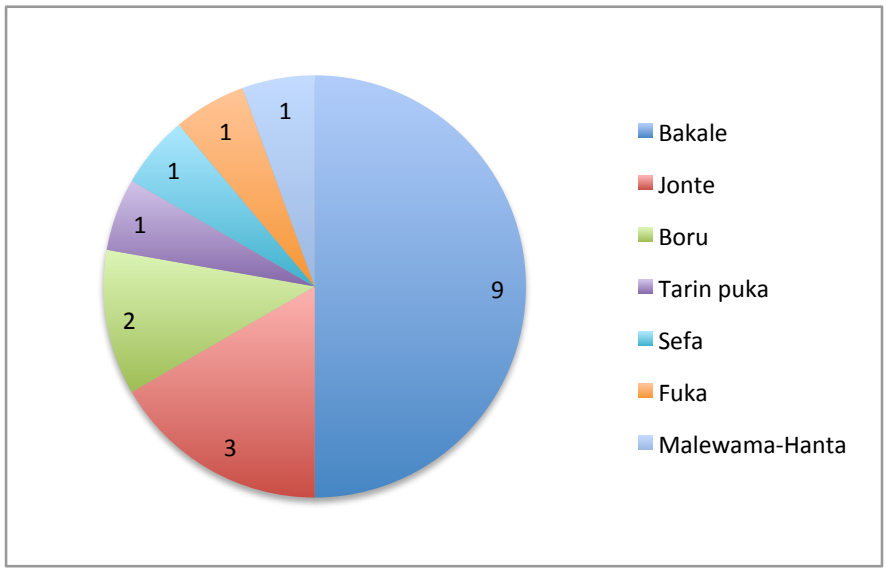


Figure 122 Frequency of responses to 'What are the local names of diseases which people can catch from cattle?', October survey

Local name of zoonosis	*Translation*	*Symptoms for human disease*	*Symptoms for animal disease*	*Prevention*
Bakale	Brucellosis	Fever, pains and abortion	Abortion and hygroma	Boil milk, avoid contact with cattle urine
Jonte	Malaria	On and off fever (on alternate days)	Not specified	Boil milk, herbs, don't know
Boru	FMD	Not specified	Not specified	Isolate infected animal
Tarin puka	Tuberculosis	Coughing, very dry, weakness, dizziness	Not specified	Stop taking milk raw
Sefa	Anthrax	Not specified	Sudden death and bleeding from nose	Do not eat meat of infected animals
Fuka	Don't know	Not specified	Not specified	Not specified
Malewama-Hanta	Clostridial disease or fluke (fasciola gigantica?)	Cough	Not specified	Not specified

Table 113 Diseases perceived to be transmissible from cattle to humans

9.3.2.2 Perception of household human brucellosis status

Only seven respondents out of 80 reported having a person with brucellosis in their household. All cases were alledged to have been diagnosed by a doctor. Interviewees were asked if they knew of any other human cases in KGR which yielded three cases, giving a total of 11 cases. None of the households reporting cases of brucellosis were found to have serological positives. The symptoms described for the seven household cases were recurrent fever, general body pains and abortion. Dr Jamo, the local community doctor was reported to have diagnosed the cases but a KII with Dr Jamo revealed that he has never diagnosed a case of brucellosis in his career.

No butchers complained of recurrent fevers or other clinical signs consistent with brucellosis, which aligns with the serological picture described in Chapter 7 and 8. This finding also supports observations of the KGR private clinic medical doctor who reported never having seen a case of brucellosis since setting up practice in the KGR in 1998. Dr Jamo previously worked in a tertiary hospital in Kaduna and did not diagnose brucellosis cases there either. He described brucellosis as: "*Being*

mostly diagnosed clinically, or you do the test for TB and then if it is not TB you check for brucellosis by doing a serological test".

He stated: "*we don't think to look for brucellosis because there is no national campaign for this disease, unlike TB"*. His conclusion was that brucellosis was a condition learnt about at medical school as a rare differential diagnosis for TB.

9.3.2.3 Practices relevant to animal-human transmission

9.3.2.3.1 Milking, milk processing, milk consumption and the milk chain

9.3.2.3.1.1 Milking

Men questioned about milking habits declared: "*Milking is like farming, something which every member of the family has to do. Children learn from their fathers. Even ladies will learn how to do it. The women can only milk the cows when there are no men around. Usually, if there are men, it will be the men who do the milking"*.

Women responded by stating: *"Men milk the cows. Anyone who knows how to milk can do it, but no women ever milks"*.

Sick cows are not milked, the milk is reported to be very sour and herdsmen let the calf suckle instead. The majority of respondents answered 'no' to the question: 'do you milk cows that are sick' (Figure 123). The types of diseases for which a cow would not be milked include bakale (response provided by two households, and demonstrates that awareness of human transmission via milk is poor (Figure 124).

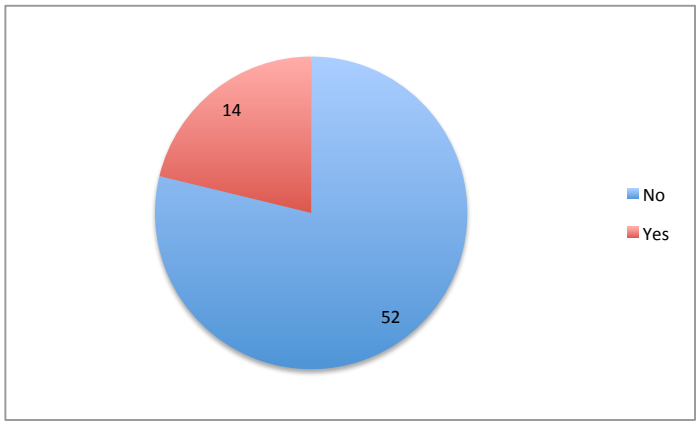


Figure 123 Frequency of responses for milking and drinking of milk from sick cows, October survey

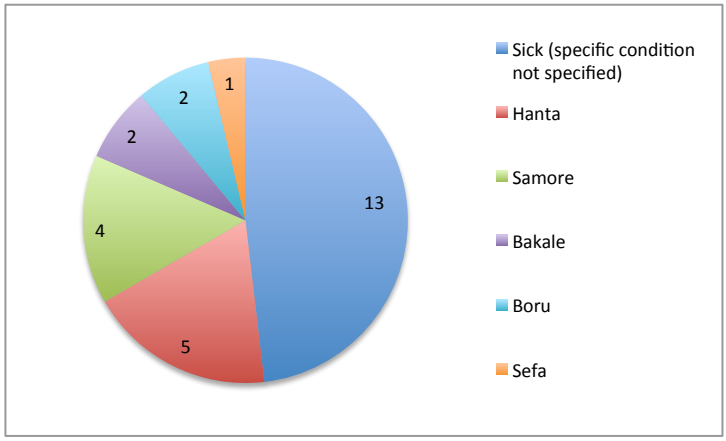


Figure 124 Frequency of responses for type of sickness for which a cow is not milked, October survey

9.3.2.3.1.2 Milk processing

After milking, milk is handed to the women of the household. Although milk, is processed by men and women, women dominate this task (Table 116). The first step in milk processing involves sieving, and occasionally boiling. The women state: *"Sometimes we will give the children raw milk before we process it, and adults will also take some raw milk"*.

The women were questioned on the way milk is boiled: *"We will heat the milk until it bubbles. The time this takes depends on how good the flame is. We wait until the milk goes up and then we remove it from the fire because otherwise it will boil over"*.

From this description, milk is unlikely to be boiled for the recommended 5-10 minutes required for pasteurisation.

Milk not directly consumed by the household is processed into *nono* (yogurt), *wara* (cheese), *nebam* (butter), *kindirmo* (between butter and yogurt) or *nyamri* (maize or corn porridge). Women of fifteen years or older are responsible for this task.

To make nono women explained: *"We take milk from the cows, sieve the milk, get a pot and boil the milk, allow it to cool, then transfer the milk to a plastic container. Then we get some sour nono and put it inside the milk in the covered container. We leave this until the next day and then have kindermo, and if we separate the upper fat we can make butter with this, and the lower part is usually nono"*.

Wara is prepared by boiling milk, at boiling point seeding with sour nono and allowing the two to boil together until the solids separate from whey. A sack/muslin sieve is then used to remove all water, the mixture is flattened with a stone and cut it into small pieces (slices) and fried in butter or groundnut oil.

To make nebam: "*The fat from nono (upper part) is removed and put in a special calabash and shaken for a long time. Butter is used for cooking, it is not eaten 'straight' so it goes through a second stage of cooking".*

Table 114 shows that even though the majority of people boil milk before preparing nono, wara and nebam, some will prepare these from raw milk.

9.3.2.3.1.3 Milk consumption

The risk associated with consumption of dairy products applies mostly to drinking of raw milk since other milk-products are mostly made from boiled milk.

Interviews show that raw milk is mostly consumed by children, followed by men and then women (Figure 125). 88% of the 1126 individuals sampled during the October survey reported drinking raw milk. The consumption of raw dairy products at household level was found to be 50% for the March survey and 92% for the October survey. Most people in KGR have exposure to raw and potentially *Brucella* infected dairy products. To try and gauge the level of exposure, the March questionnaire examined the percentage of milk consumed raw at household level (Figure 126), which ranged from zero to 100%. Table 116 shows that slightly more males (94%) consume raw milk than females (83%). The consumption of raw milk is fairly constant across the different age groups.

The March questionnaire confirmed that Fulani do not consume milk from small ruminants as they keep meat rather than dairy sheep and goat breeds.

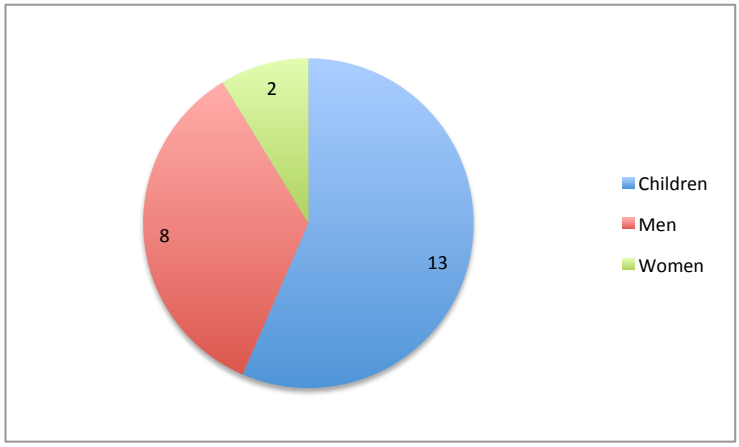


Figure 125 Frequency of responses for type of people in the household who consume the majority of the raw milk, October survey

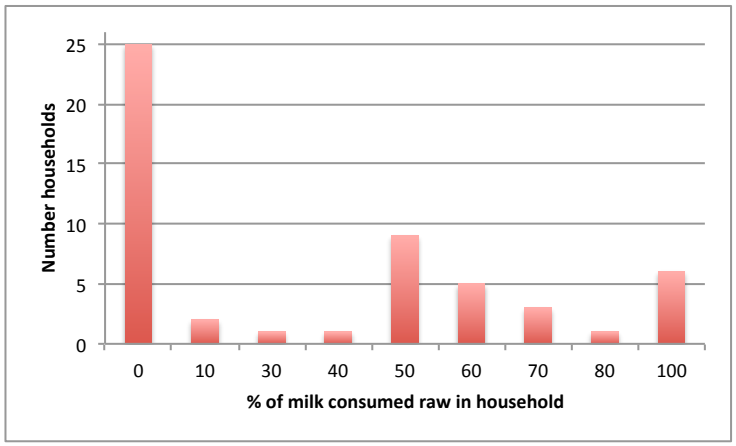


Figure 126 Frequency of percentage raw milk consumption at household level, March survey

The rationale for drinking raw milk was discussed during the 'from cow to mouth' FGDs. The men stated: "*drinking milk fresh gives them more satisfaction and more good health"*. One man said *"when milk is boiled it tastes like pig milk"*, a statement which, coming from someone of Muslim faith, is not a compliment! Another stated that according to their 'beliefs' "*when the milk is boiled it is turned into something else and it is no longer real milk*". Not everyone agreed, however. One man was very vocal in expressing that boiled milk had a better taste.

The women shared more pragmatic views: *"when we are busy we do not have time to boil milk, so we will take it raw"*. One young and educated woman stated that: *"boiling is done to get rid of infectious agents"*. Another woman declared; *"milk that is boiled is sweeter and tastes better"*.

One woman shared a superstitious belief: *"I have heard this belief that if we boil the milk of cows they will give less milk but I don't believe in it. It is more the nomads that believe in that, more sedentary Fulani do not believe in it"*.

This statement is in line with the findings of the questionnaire, which show that households belonging to the Yabaji clan had very strong opinions about the importance of drinking raw milk. Members of the Yabaji clan have held on more to their traditional 'Bororo' nomadic cultural heritage and beliefs, claiming that boiling of milk will burn and damage the teats of the cow the milk came from through *'voodoo magic'*. The women reported that during milking men often take raw milk from the teat: *"Young boys who go to the bush rely on raw milk as a source of food during transhumance"*.

Children, persons performing regular milking of cows and those accompanying cattle on transhumance consume the most raw milk and therefore are most at risk, but the vast majority of individuals consume at least some raw milk and are also exposed to the risk of contracting brucellosis through this route.

A. Consumption raw milk	*N HH (Yes)*	*% HH (Yes)*
March survey	54 (27)	50.0
October survey	49 (45)	91.8
B. Consumption of raw milk	*N ind (Yes)*	*% ind (Yes)*
October survey	1125 (988)	87.8
C. Processing of dairy products	*N ind (Yes)*	*% ind (Yes)*
October survey	1125 (820)	72.9
D. Processing of dairy products	*N HH (Raw)*	*% HH (Raw)*
Nono (yogurt)	70 (19)	27.1
Wara (cheese)	11 (1)	9.1
Nebam (butter)	60 (6)	10.0

Table 114 A. Number and percentage of HH tconsume raw milk

B. Number and percentage of individuals who consume raw milk, October individual person questionnaire administered to all persons blood sampled; C. Number of individuals who partake in milk processing, October individual person questionnaire administered to all persons blood sampled; D. Number of households that produce nono, wara and butter, and number and percentage of households which use raw milk to prepare each product

9.3.2.3.1.4 Milk sale and purchase

Households were questioned on practices surrounding sale of surplus milk. All households sell milk, either to teashops in the centre (Tampol) or to *nono* sellers in the market. Customers also come directly to the homestead to buy milk. Milk is purchased occasionally when a household has not produced enough of its own to meet household demands. A FGD with the women's cooperative the 'Rise of Dawn' revealed that the way that milk is sold in KGR has changed over time: "*During the early era of the grazing reserve, when there was good control of flies and many animals, there was a company 'MILKOPAL' from Kaduna that used to buy up all the milk and collect it. They would measure the quantity, process it and sell it for you. This collapsed due to the poor control of flies and lower number of animals. Now we milk the animals and boil and process or sell ourselves. Fresh milk is taken directly to coffee shops and they boil it and sell it. Either way we must transport the milk to the market to sell our products. There are now plans for a new processing plant as part of the Kaduna Agricultural Development Project which was funded by the state government. The idea is that if you have surplus milk, you register the milk you have brought and store it in the refrigerated bulk tank in the purpose built milk collection centre. At the moment there is a large loss of milk as we have no storage facilities, and the idea is that we want to preserve the extra milk we produce for as long as possible. There are no plans to sell this excess milk outside the reserve, it is for use within reserve, simply for storage so we get less wastage."*

The 'from cow to mouth' FGD responses from women revealed that most households keep 50% of the milk produced on average to feed themselves, and that 50% is destined for sale. Men said the proportion of milk sold depends on the number of people in the family and the size of the herd. When questioned on who goes to sell the milk products and where, the group of men replied that they did not know as "*from the point the milk gets into the hands of the women it becomes a woman's affair"*!

Women answered: "*Young girls who do not have young children are the ones sent to sell the milk in the market centre, Tampol, because they might meet a man who would make a nice husband"*.

9.3.2.3.2 Contact with animal birthing and abortion products and animal slaughtering

Only 31% of people have contact with animal births (Table 115) and the majority are men (Table 116). In the June survey, 22% of respondents claimed to use bare hands to manipulate birthing materials. Manipulation with bare hands was higher for dealing with abortion products (51-88%), the reason for this being that: *"Sticks can be used if the foetus is small but that they must use hands to move the product of abortion if it is bigger as it is the only way to lift the material"*.

Animal slaughter is undertaken by 25% of persons overall, the majority of which are men (Table 116). The FGD with 12 of the KGR butchers revealed that all animals slaughtered came from the KGR, hence their exposure risk is theoretically proportional to the disease burden in KGR animals.

A. Pick up products of abortion with bare hands	*N HH (Yes)*	*% HH (Yes)*
March	51 (26)	51.0
June	16 (14)	87.5
B. Pick up birthing materials with bare hands	*N HH (Yes)*	*% HH (Yes)*
June	18 (4)	22.2
C. Assist with animal births	*N ind (Yes)*	*% ind (Yes)*
October	1125 (353)	31.4
D. Perform animal slaughter	*N ind (Yes)*	*% ind (Yes)*
October	1125 (282)	25.1

Table 115 Responses to practices surrounding products of abortion, birthing materials and animal slaughter

A. Number and percentage of respondents who pick up products of abortion with bare hands, March and June HH questionnaire; B. Number and percentage of respondents who pick up birthing materials with bare hands, June HH questionnaire C. Number and percentage of individuals who have contact with animal birthing products and assist with animal birthing, October individual person questionnaire administered to all persons blood sampled; D. Number and percentage of individuals who perform animal slaughter, October individual person questionnaire administered to all persons blood sampled.

		Consumption raw milk		*Processing of milk*		*Assist animal births*		*Perform animal slaughter*	
	Total	N Yes	% Yes	N Yes	% Yes	N Yes	% Yes	N Yes	% Yes
Sex									
Female	630	523	83.0	452	71.7	15	2.4	4	0.6
Male	495	465	93.9	278	56.2	338	68.3	278	56.2
Age									
6-15 y.o.	354	313	88.4	213	60.2	52	14.7	21	5.9
16-30 y.o.	416	370	88.9	331	79.6	140	33.7	108	26.0
31-50 y.o.	249	211	84.7	196	78.7	106	42.6	103	41.4
>50 y.o.	106	94	88.7	80	75.5	55	51.9	50	47.2

Table 116 Comparison of number and percentage of individuals who engage in various practices

9.4 Discussion

The two main questions surrounding the brucellosis picture for the KGR are:

1. Why is the prevalence of cattle brucellosis so low in the presence of *Brucella*?
2. Why is there no human disease in the presence of a cattle reservoir of *Brucella*?

The qualitative data was examined to assess if knowledge, attitudes and practices of the KGR community are part of the answer to these two questions.

9.4.1 Low cattle brucellosis prevalence

The low individual cattle prevalence in the presence of *Brucella* is an unexpected finding. The term ‘unexpected’ is used because the perception, reflected in published material (see Chapter 8), is that brucellosis prevalence is higher in extensive pastoralist systems than intensive commercial settings. Nomadic pastoralists are perceived as the main reservoir of infectious diseases in Nigeria, spreading disease to sedentary farms through transhumance. Despite finding a low individual seroprevalence, herd prevalence was higher. This suggests that at individual herd level, intra-herd transmission is very low. The moderate herd prevalence observed suggests that inter-herd transmission is more important.

In the extensive pastoralist system, the calving interval is longer and the birthing frequency lower than in intensive systems. Opportunities for transmission through birthing fluids are thereby lower. Cows calve away from the herd in the KGR, further reducing opportunities for transmission.

KGR herds are constantly on the move, being taken away from the homestead for grazing within the KGR, or going on long-range transhumance. This means that if an animal aborts, other cows have only a short opportunity for contact with products of abortion before moving on. Most respondents stated removing products of abortion, further reducing the opportunity for contact. A herd boy accompanies the cattle at all times so abortions are spotted immediately and the aborted material removed promptly before other cattle in the herd have the opportunity to lick or nuzzle it.

The questionnaire findings suggest that Fulani knowledge of bakale symptoms and transmission mode in animals is relatively good. Gaps in knowledge include propensity for transmission via birth fluids and materials or products of abortion. Because they can recognise the disease, the questionnaires and FGDs suggest that the KGR Fulani have a good intuition for spotting the disease in their animals and are good at applying disease-reducing strategies. Selling cows that are thought to have bakale (because of infertility or abortions) and sale of bulls with hygromas is probably the practice with the most impact in reducing inter-herd transmission.

Intra-herd transmission may be promoted through management or husbandry practices promoting transmission between herds. The indiscriminate purchase of bulls from markets through traders (who claim they do not look for signs of disease and base their decision on 'looks') is one way in which brucellosis infected cattle could be introduced into brucellosis-free herds. Not all households purchase new animals in this way; some have good awareness of the importance of biosecurity measures and will only buy bulls or cows directly from other KGR herdsmen *"whose herds they know are not infected"*, although this is difficult to confirm with any certainty based on observations and absence of clinical symptoms alone.

Another way the disease could be disseminated between households is through the sharing of the infected Friesian bulls obtained by the Dairy Cooperative from the intensive IDF/WAMCO dairy farm in Vom. Other than for reasons of genetic

improvement, however, the vast majority of households prefer to use their own bull for "*fear of bakale*". This means that risk of transmission due to inter-herd breeding will only apply to the 30% who share bulls and cows with other households, and to the members of the cooperative using the Friesian bull.

Almost all herds have contact with other herds during grazing and at watering points due to the communal grazing practices and frequenting of the few dams on which the entire community depends. The herdsmen also described contact of their cattle with wildlife. Even though the Fulani explain the importance of managing and grazing their herd as far away from other herds as possible to prevent transmission of infectious diseases, the high animal densities and close contact during co-grazing or drinking promote transmission. Numerous questionnaire respondents associated bakale with time spent around dams and more specifically water, suggesting this could be an important opportunity for transmission.

Vaccination was reported undertaken by only one household; such a low vaccination coverage will have no impact on preventing inter-herd transmission in this system.

9.4.2 Absence of human infection in presence of cattle reservoir

There were no positive humans from the 1126 individuals screened during the October survey. This correlates with the poor knowledge of questionnaire respondents on human brucellosis symptoms and transmission; if the human form of disease does not exist in the community, they are unlikely to be familiar with its characteristics. The medical doctor interviewed, who has practiced in the KGR for over a decade, was also very confident that there is no human brucellosis in the KGR. This finding, however, is paradoxical in the presence of cattle brucellosis, confirmation of circulating *B. abortus*, and presence of numerous risk factors for transmission of cattle disease to humans. For example, 88% (including both men and women of all age groups) claimed to consume raw dairy products. Herdsmen have intimate and direct contact with birthing fluids during parturition and with products of abortion. Butchers were also sampled during the survey and none were found to be infected despite using no protection during butchering.

The reason for the apparent absence of human infection in the presence of a cattle reservoir and engagement in risky behaviours is unclear. A combination of factors could account for the absence of human brucellosis. There are a number of possibilities; i) Circulation of in KGR of a *Brucella* biovar of lower virulence and lower pathogenicity in humans could explain this finding; ii) that brucellosis infections are present but are not detected by the conventional serological tests ii) transmission opportunities are minimised as only a very low percentage of dairy products are consumed raw. Most milk consumed by the household is processed into nono, nebam or wara, the milk for which is boiled as part of their preparation in the vast majority of households. The Fulani claim that they do not milk 'sick' cows, and this could reduce the likelihood of infected milk making its way to the household; iv) children are exposed to low levels of *Brucella* in infected raw milk at a young age, they could develop immunity in the same way that a vaccine would stimulate lifelong immunity and v) that such low numbers of cattle are infected (around 1%) and at this low prevalence, infection rates in livestock have not reached a threshold for spill over and this combined with intuitive disease-mitigation practices may reduce the exposure to a low enough level so as to prevent human infection entirely.

The absence of human brucellosis in the presenece of an animal reservoir and widespread consumption of raw dairy products is encouraging news for the KGR community. Parallel animal and human population studies in other Fulani communities of Nigeria would confirm if this is a unique finding or if this applies to other extensive pastoralist communities in Nigeria and West Africa. The replication of this finding in other settings could have far-reaching relevance to prioritisation of zoonosis control in sub-Saharan Africa.

9.4.1 Descriptive model of brucellosis transmission in the KGR

A descriptive model of brucellosis transmission in KGR, incorporating the environmental and epidemiological elements presented in chapters 8 and 9 is shown in Figure 127. The system related aspects (herd dynamics and management, human behaviour) act as drivers or preventers of transmission. The figure demonstrates the linkages between the different components of the system and the influence of different factors on the force of infection.

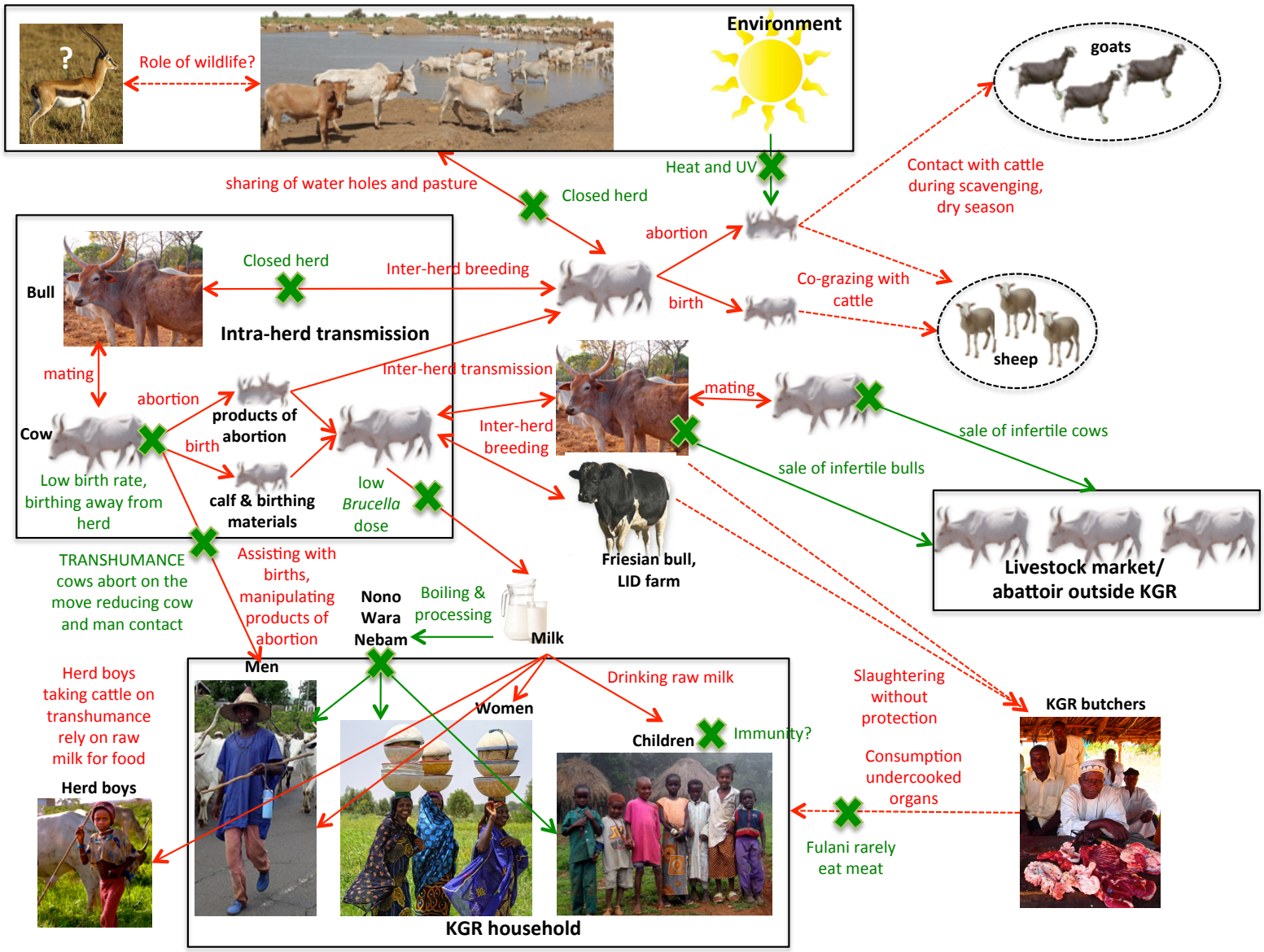


Figure 127 Simple transmission model of brucellosis transmission in the KGR

10 Chapter 10 Brucellosis control

The first section (10.1) of this Chapter discusses prospects and recommendations for control in Nigeria. The second section (10.2) looks specifically at recommendations for control in KGR based on the findings of the KGR surveys. Analysis of questionnaire data collected during the October survey on KGR community attitudes to brucellosis control in the KGR is included in the second section.

10.1 Brucellosis control in Nigeria

The investigation of brucellosis in Nigeria has yielded evidence to suggest that brucellosis is a significant public health issue and an economic burden to the livestock industry (see Chapter 6). The disease persists both in the endemic pastoralist setting at hypoendemic level and at a higher level in intensive commercial systems. This was recognised early on and despite brief vaccination and test-and-slaughter strategies (see 10.1.1 below), very little has been done to reduce the prevalence of this disease in the animal reservoir and the human population. This is despite the existence of control tools that have been used successfully in many parts of the developed world to eradicate the disease.

10.1.1 Historical control strategies in Nigeria

Brucellosis control was initiated in colonial Nigeria in 1917; vaccination was used to address widespread bovine abortions in government-owned farms and local production of a liquid S19 vaccine began. A test and slaughter policy was implemented (Falade, 1981b), and its failure was attributed to a lack of rigor in implementation. Production of lyophilised S19 started in 1950 (Ocholi et al., 1993), and by 1951, brucellosis eradication and control programmes had established brucellosis-free stock and reduced overall prevalence to less than 5% on government farms (Mai et al., 2012). Efforts waned and vaccine production discontinued in 1954 (Ocholi et al., 1993). Today there is no government policy for brucellosis control in Nigeria. NVRI is the national reference centre for brucellosis in Nigeria. Since no control policy for brucellosis exists, samples are submitted for laboratory testing on an individual or ad hoc basis and on the initiative of either the farmer or the veterinarian when brucellosis is suspected. Because of the large distances involved

and the poorly organized transportation systems, the number of samples submitted is generally low and in most cases from nearby states only (Bertu et al., 2012).

10.1.2 Barriers to control

Barriers to control have been and continue to be multifaceted. The evidence on brucellosis has been fragmented and despite strong lobbying for control from the Nigerian brucellosis research community, this has not been sufficient to build a strong enough case to convince policy makers to prioritise brucellosis control. Lack of recognition is rooted in the under or mis-diagnosis of the disease (due to non-specific presentation both in animals and humans) which leads to under-reporting and under-estimates of the true burden. In the absence of active surveillance for the disease and in combination with lack of pathognomonic signs and mis-diagnosis of cases, official reports for brucellosis reflect only the very tip of the iceberg. Brucellosis is also competing for prioritisation with other widespread diseases of epidemic nature such as FMD, from the veterinary perspective and with pandemic conditions such as malaria, TB and HIV with regards to human health.

Part of the issue of under-reporting is rooted not only in the absence of clinical suspicion but also in limited diagnostic capacity and expertise. Despite the existence of cheap and efficient diagnostic tests for brucellosis diagnosis in humans and animals, few laboratories will undertake brucellosis serology and bacteriology outwith research, and even if they are capable of doing so, the misconceptions surrounding brucellosis diagnosis often leads to misuse of tests and misinterpretation of results (see Chapter 6 and 7). The ability of laboratories to accurately interpret and use diagnostic tools is paramount in control situations, as use of vaccines results in serological interference and selection and interpretation of tests becomes even more critical. In order to overcome these barriers, two things are necessary: the first is education of veterinary and public health laboratory professionals on judicious use and interpretation of diagnostic tools and the second is the setting up of brucellosis reference laboratories in Nigeria. This will ensure expertise and capacity building for brucellosis diagnosis, which is an essential component of any control strategy.

The existence of a brucellosis reservoir in nomadic or semi-nomadic pastoralist livestock and communities also presents a stumbling block from the perspective of

control. The first reason for this is that the migratory habits of these populations make any control intervention challenging. At a fundamental level, reliable and up-to-date estimates of livestock populations owned by pastoralists and are not available (Bale et al., 2003b). The second reason is that the political-will is not there: the authorities are not prioritising the interests of pastoralist communities because they are largely uneducated and thereby unable to voice or articulate demands within the existing political framework. Their ability to lobby for their rights is undermined by their incapacity to enter the political domain through political representation. Hence at a basic level we are not dealing with neglected zoonoses but neglected communities, whose interests are undermined through political marginalisation.

10.1.3 How much does it cost and who pays for control?

10.1.3.1 Socioeconomics of control

A detailed evaluation of societal costs of brucellosis is beyond the scope of this thesis. Moreover reliable estimates of cost would need to be based on accurate infection rates for the different species affected by brucellosis across the spectrum of livestock production systems. These, as well as accurate livestock population figures and other parameters (such as proportion of at risk mature females of breeding age, conception rates, abortion rates etc.) are not readily available for Nigeria, which makes any estimation of costs complex if parameters have to be modelled.

The societal cost of brucellosis has to take into consideration not only animal production losses but also monetary expenditure on animal health (which include veterinary service and livestock keeper costs), monetary expenditure on human health (including public health and private sector costs) as well as non-monetary losses to human health (DALYs). The economic argument for the control of zoonoses, once all these costs have been aggregated, is a compelling one due to the 'double whammy' of having a dual burden of disease in both humans and animals. The opportunity to control human disease through animal interventions is also financially appealing because the cost of control in the animal reservoir is offset by the benefits of simultaneously reducing both the human and animal burden of disease. Cost-sharing of control interventions across sectors in proportion to the benefits accrued by each sector (as a result of reduction in human and animal cases

and thereby costs of disease) presents more affordable financing frameworks for individual sectors. Control of zoonoses like brucellosis have been demonstrated to be highly cost-effective, and this is the most powerful argument to exploit and use as an advocacy tool in convincing policy makers of the necessity of brucellosis control.

Three studies have evaluated the cost-benefit of brucellosis control and/or the financial losses due to bovine brucellosis in Nigeria using the same methodology. Esuruoso (1979) calculated losses due to brucellosis for the whole of Nigeria whereas Ajogi et al. (1998) have focused on two grazing reserves in Northern Nigeria. Ajogi and Akinwumi (2001) estimated the cost of brucellosis per herd for the same grazing reserve setting as Ajogi et al. (1998). These studies calculate estimated financial losses due to bovine brucellosis in the form of calf and milk losses resulting from *Brucella*-associated abortions, bareness following abortion and retention of afterbirths. Interestingly the study by Esuruoso (1979) was commissioned by the Federal Authorities as part of a feasibility study into the control/eradication of brucellosis. The impetus and growing recognition of the relevance of brucellosis in Nigeria was partly attributable to researchers such as Esuruoso (1979) raising the profile and awareness of this disease and the building up of a portfolio of evidence which could used as advocacy for its control.

Esuruoso (1979) estimates that the total financial losses per annum due to bovine brucellosis in Nigeria are 223.88 million USD. The overall animal production losses in the two grazing reserves as calculated by Ajogi et al. (1998) is 149,481 USD, which per herd costs the nomads 42 USD for an average of 47 cattle in Wase and 29 USD for an average of 54 cattle in Wawa-Zange grazing reserve (Ajogi and Akinwumi, 2001). Ajogi and Akinwumi (2001) calculate that nomads in Wase grazing reserve make 250 USD per herd annually, and that with the cost of 42 USD for presence of brucellosis, this reduces the profit to 208 USD (hence constituting a 17% loss). In Wawa-Zange, the annual cost of cattle production is estimated at 180 USD (hence the nomads do not make a profit), which with a brucellosis cost of 25 USD per herd results in total losses of 209 USD. This highlights that cattle production as practised by nomads is not profit oriented, that the costs of managing cattle are high especially when the opportunity cost of labour input by the nomad's

family is taken into consideration, and that brucellosis has an impact on the overall profit or loss at herd level.

Esuruoso (1979) makes some preliminary estimates of the cost of brucellosis control and calculates that 214 million USD could be saved in the first year of control, with greater benefits to be expected in subsequent years.

These studies, while giving an indication of the cost of brucellosis nationally and for the two grazing reserves, do have some limitations. The calculations are based on cattle production losses and do not take into consideration the total societal burden disease [which consists of a) potential loses due to monetary expenditure due on human health by health services, patients and loss of income from sufferers (due to loss of days of work due to ill-health or taking time off to visit hospitals); b) non-monetary losses to human health (DALYs or cost of human agonies from brucellosis infection); c) monetary expenditure on animal health by health services and animal keepers]. Losses are only calculated for cattle, which while being considered to be the most important livestock source, reservoir and sufferer of brucellosis, only constitute one of many ruminant species (sheep, goats, camel) whose production is affected by brucellosis.

Esuruoso (1979) bases his calculations on the assumption that 50% of the mature breeding females at risk of brucellosis infection are in settled herds (belonging to Fulani owners, Fulani herdsmen, co-operatives corporations and government investigation and breeding centres) with high infection rate (prevalence figures were based on previous findings (Esuruoso, 1974a, Esuruoso, 1974b, Esuruoso and Hill, 1971, Esuruoso and van Blake, 1972), and that the other 50% are in migrant herds with a low infection rate (3.1% prevalence as based on (Esuruoso, 1974a).

While it is important to calculate losses separately for the extensive nomadic versus the intensive settled livestock production systems due to inherent differences in brucellosis epidemiology and burden, the assumptions by Esuruoso (1979) pose two problems, firstly the epidemiology and prevalence is likely to be different between intensively-managed (commercial) settled herds and extensively managed Fulani settled herds, hence grouping of settled herds as a single category is an oversimplification leading to overestimation of overall prevalence for the two very

different management systems. Secondly, the infection rate parameter used to estimate the number of brucellosis infected mature breeding females in the settled herds was based on outbreak investigations, which are biased representing extreme or over-inflated prevalence values. These assumptions may have lead to an overestimation of the total financial cattle production losses per annum.

There is variability in clinical picture of brucellosis depending on recent (acute) versus ancient (chronic) *Brucella* introduction into a herd and livestock production system (Ferney and Chantal, 1976). This bears some relevance to estimating parameters such as conception and abortion rates for economic calculation. In immunologically naïve herds or in herds where the opportunities for transmission are increased (such as in situations of settling infected migrant herds) the disease extends rapidly and "abortion storms" storms occur. Overtime, however, even though fertility may have been compromised, abortions and stillbirths become progressively fewer (provided no new animals are introduced) possibly because of the establishment of a stalemate between the bacteria and immunity in animals that have undergone abortions, and the disease becomes chronic in some animals whereas others recover. Hence in herds that have chronic brucellosis and do not introduce new animals very few abortions occur and the disease is almost impossible to recognise clinically (Mai et al., 2012). What this means in terms of the assessment of brucellosis associated losses is that estimates should reflect these differences in abortion rates in the chronic versus the acute situation. In order to accurately calculate livestock production losses in Nigeria due to brucellosis, one must therefore firstly determine the proportion of herds in the hypoendemic brucellosis category versus those that belong to the emergence/outbreak category. Then one must define the infection rate, conception rate, abortion rate and other productivity parameters specifically for each category to capture the variability in impact of brucellosis on productivity in the early introduction versus the chronic stage of the disease in a herd.

To conclude, while previous estimates have demonstrated that brucellosis is likely to have a considerable impact on cattle productivity, more reliable data on the prevalence of brucellosis and productivity parameters in extensive versus intensive, settled versus migratory, newly infected versus chronically infected ruminant

herds/flocks (including cattle, sheep, goat and camels) is required to accurately calculate animal production losses. This component must be complemented with non-monetary losses to human health (DALYs), and monetary expenditure on human health and animal health to estimate the total societal cost of disease. If this is contrasted to the total societal cost of control, then the total societal benefits of brucellosis control (in terms of DALY's averted, reduction in livestock production losses, medical and veterinary expenditure to control the disease and in patients and livestock keepers costs) and cost-effectiveness of control can be calculated. Cost-effectiveness evaluations are powerful tools in the advocacy of zoonosis control, especially if cost-sharing across public health and veterinary sectors is established according to relative contribution to economic burden of each sector.

10.1.4 Political dimensions and conditions for emergence

There is conflicting evidence as to whether the main reservoir for brucellosis exists in intensive/settled/commercial or extensive/Fulani/migratory livestock populations. Overall, the prevalence of brucellosis appears higher in intensive commercial herds in Nigeria, but this may be because intensive herds have predominantly been investigated in outbreak investigations. In Fulani herds, brucellosis prevelance in pastoralist settings is highly variable ranging from 0 to 50% (see Chapter 6). Analysis of the association between transhumance and disease prevalence is complex since the migratory habits of the herds are inadequately described in most studies. Proposals for brucellosis control have often focused on restricting transhumance of pastoralists based on the premise that free movement of animals is contributing to disease spread (Bertu et al., 2012). In this section the political versus the scientific impetus and justification for 'blaming' brucellosis on the migratory habits of pastoralists are explored.

Most brucellosis transmission occurs due to abortion or birthing of infected females or during mating of infected males with females. For transmission to occur between individual animals of different herds, breeding females would need to abort/give birth and contaminate each other, and mating would need to occur during co-grazing and co-watering of herds. Pastoralists can be semi-nomadic and practice seasonal migration or nomadic and practice year round migration. Seasonal migrants do not

usually take cows in the last trimester of gestation or recently calved animals on migration. These animals are kept at the permanent homestead to provide milk for the household. This husbandry practice while permitting intra-herd disease transmission of disease minimises inter-herd transmission. For year-round nomadic herds, the likelihood of cows or small ruminants aborting or giving birth during periods of contact with other herds is limited. *Brucella* does not persist as long in the environmental conditions of the open savannah (high temperatures, ultraviolet effect of sun), which also minimises the opportunities for transmission should infected products of abortion contaminate the environment (Ishola and Ogundipe, 2000, Nuru, 1975, Nuru, 1974, Nuru and Schnurrenberger, 1975, Bale et al., 1982).

Transhumance prevents intra-herd transmission, as animals are less likely to have the opportunity to lick and smell products of abortion. Breeding females in extensive herds give birth to fewer calves in a lifetime (see Chapter 5), which again reduces opportunities for transmission. Pastoralists operate more of a closed herd system and introduce new animals less frequently into the herd than intensive farms. The Fulani also report quickly selling any animal that aborts or they suspect is infertile due to bakale or brucellosis (one of the justifications given for the high prevalence of brucellosis observed in trade cattle). All of these conditions support the hypothesis that brucellosis is likely to exist at lower levels in the migratory herd than the settled herd setting, an opinion shared by other studies (Ferney and Chantal, 1976).

In settled herds, opportunities for transmission are increased due to higher stocking densities, animals having greater opportunity to lick products of abortion and introduction of infected (replacement) animals into the herd. *Brucella* persists for longer in manure and manure accumulates more readily in housed (contained) animals. Infection rates are likely to be higher in settled herds that do not practice vaccination, especially those managed intensively with an open-herd system.

Brucellosis transmission would be more likely with a shift to sedentarisation of previously migratory, chronically infected herds and could result in emergence of disease, due to disturbance of the hypoendemic stability of nomadic husbandry. Intensive farms also have conditions favourable for transmission and therefore the burden of disease is likely to be high in this context.

An investigation of a large community outbreak (cattle and humans) in Ibapara District by illustrates this point (Alausa, 1979). Ibapara district was described as being home to i) 'nomadic herdsmen that move only within the district, and within few kilometres from previous settlements'; ii) government-owned settled herds and iii) other nomads from the northern parts of the country that periodically migrate to the district. The serological results and observations of the investigation pinpoint the origin of the outbreak to local 'sedentary' Fulani nomads. The outbreak occurred in this group because i) the Fulani herdsmen stopped selling cattle to butchers (they usually only sell cattle when there is a high and favourable calf crop so this indicates that herd productivity was affected); ii) herdsmen in Ibapara district experienced severe calf losses from recurrent bovine abortions and infertility (but these losses were more severe in the local nomadic herds); iii) all 11 herds with bovine brucellosis belonged to local Fulani nomads (of a total of 25 herds comprising commercial and Fulani herds); iv) many Fulani herdsmen in Ibapara complained of being unwell and unable to look after their cattle properly during the outbreak, suggesting that their ill-health could be linked with the outbreak in their cattle and v) the usual periodic migration of nomads from the North ceased one year prior to the brucellosis outbreak in the district because of the sahelian drought (hence it seems unlikely that their movements were at the origin of this outbreak).

The reduction in migratory behaviour of these local Fulani nomads can be assumed to be a recent phenomenon, which triggered emergence of brucellosis in their herds. The outbreak or emergence was likely due to brucellosis shifting from a hypoendemic chronic status to a hyperendemic situation where, due to increased opportunities for transmission between infected animals and susceptible animals, an abortion storm ensued. The situation in the human population reflected the outbreak in the animal population.

If correct these assumptions suggest a disparity between the presumption that nomadic behaviour promotes brucellosis transmission and the reality where sedentarisation and intensification of previously migratory extensive systems promote emergence of brucellosis. In the absence of conclusive evidence it is

interesting to consider why the majority of authors may attribute brucellosis spread to pastoralist movements.

The discordance between the evidence and the conclusions being drawn in many of the reviewed papers can be ascribed to the three main factors. Firstly, there is a general misconception that brucellosis transmission is similar to that of highly infectious airborne diseases such as CBPP or FMD. Movement and contact between herds is much more important for these diseases than for brucellosis, because transmission occurs more readily over a shorter period of time. The second factor is that 'the spread of infectious diseases' is often used as a blanket argument in favour of sedentarisation of nomadic populations (Iyayi et al., 2003). Whereas reduction of exposure to infectious diseases is a valid argument, the more pertinent argument is a political one to reduce clashes between crop farmer and nomads due to the destruction of crops by uncontrolled grazing of the latter's livestock (see Chapter 3).

The third objective of settling nomads is to improve the productivity of cattle reared in this husbandry system and to re-orientate and educate them towards a more purposeful profit targeted cattle production (Alausa and Awoseyi, 1975, Alausa, 1977, Bale and Kumi-Diaka, 1981, Falade, 1980). Traditionally nomads only sell cows when there is a high favourable calf crop or when they need cash. Many share the opinion that to develop Nigeria's cattle industry and productivity, the nomadic subsistence style of animal husbandry has to be gradually replaced with a more market oriented western style of livestock production.

10.1.5 Control tools and suitability for Nigerian context

A number of recommendations for brucellosis control, covering a wide range of approaches (some founded upon the European or American model and others that are more context-specific for pastoralist communities) have been proposed. These are summarised in Box 4. Two main opetions for control in Nigeria include sanitary prophylaxis and vaccination.

Box 4- Control strategies recommended by authors of papers reviewed

Control measures in human population

- Surveillance of brucellosis in human population
- Surveillance and treatment of occupational risk groups
- Screening of febrile patients for brucellosis
- Establishment of diagnostic laboratories
- Human vaccination of risk groups
- Regulated pasteurisation
- Education of risk groups
- Education of consumers

Control measures in animal population

- Cattle vaccination
- Small ruminant vaccination
- Test and slaughter
- Migration restriction of pastoralists
- Regulated importation and trading
- Regulated animal movements
- Surveillance in animal population
- Regulated abattoir establishment and practice
- Official reporting system

General recommendations

- State-focused control programme
- Collaboration between medics and vets

10.1.5.1 Sanitary prophylaxis in animals

Sanitary prophylaxis of brucellosis in animals incudes, the animal movement control, surveillance, isolation of animals during the peripartum period and the disinfection of premises and fomites to reduce the spread of disease. *B. abortus* can survive for a long time in liquid manure. Xylene, calcium cyanamide, sodium hypochlorite and formaldehyde have all been shown to destroy brucellae on contamined surfaces.

Animal movements of relevance to brucellosis spread in Nigeria consist of i) importation of livestock from neighbouring countries (Niger, Cameroon, Burkina Faso, Chad, Benin Republic etc.) (Mai et al., 2012, Alausa, 1979b, Bale et al., 2003b, Cadmus et al., 2009, Ishola and Ogundipe, 2000, Bertu et al., 2012) and ii) year-round or seasonal transhumance of nomadic and semi-nomadic pastoralists respectively. Currently the illegal importation of livestock across borders makes the

surveillance of brucellosis status in imported animals problematic. Tighter importation regulations would need to be ratified and implemented and more border posts established in order to, firstly, be in a position to monitor animal movements across borders, and secondly, confirm that imported livestock are brucellosis-free.

The control of pastoralist transhumance, briefly touched upon in 10.1.4 above is a more problematic and emotionally charged issue. Transhumance is a survival strategy employed by pastoralists, practised for millennia and which enables livestock production to be undertaken in areas with seasonal variation in pasture quality and availability. Ecological zones which offer grazing for only a limited period each year can be exploited for that short duration, with animals having to be moved between different ecological/rainfall zones to ensure year-round accessibility to grazing. Despite political momentum to sedentarise nomads in the 1960s-1980s to resolve land-clashes between pastoralists and farmers, the mixed success of these schemes seems to suggest that settling nomads is a complex issue, and one which may encourage emergence of brucellosis (see 10.1.4).

The obstacles to restricting the migratory movements of pastoralists and their livestock are multiple: firstly there is the socio-cultural issue of migration being a way of life, but more importantly there is the limited availability of year-round rangeland in Nigeria and the fact that the provision of supplementary fodder during the dry season has not been suitably resolved. A precursory reflection would suggest that the livestock of pastoralists would starve if they were unable to undertake transhumance. Hence at this time ‘controlling’ pastoralist movements seems like a difficult compromise to reach. On the one hand there is the hypothesis that settling nomads could reduce the transmission of infectious diseases, but on the other the carrying capacity of the land available is not sufficient to sustain the nomads and other competing end-users of environmental resources such as farmers.

In contrast, however, there is the contradictory hypothesis that settling nomadic populations does not in fact reduce brucellosis transmission and that the disease exists in this system at a hypoendemic or ‘steady’ state (endemic stability?).

The real animal and public health issue arises with the settling of previously migratory populations. In this situation the change from a nomadic to a settled

system of husbandry may promote emergence of brucellosis, both in the primary animal host population and in spillover hosts such as humans. More studies are necessary to gather evidence to confirm or refute the above conflicting hypotheses before recommendations are made at policy level on restriction of pastoralist movements for the control of brucellosis.

10.1.5.2 Sanitary prophylaxis in humans

Although prevention of human brucellosis should focus on the animal disease, sanitary prophylaxis in humans is very important for the Nigerian context because of the technical, economic and social difficulties associated with control of brucellosis in the animal reservoir. Indeed in many situations, there is little alternative but to reduce the risk of human infection through personal hygiene, adoption of safe working practices for occupationally exposed risk groups, protection of the environment and food hygiene.

Occupational exposure is the main source of human infection. Moreover, in Nigeria a large proportion of the population (including pastoralists, small-scale traditional farmers and intensive livestock keepers) is directly exposed to brucellosis through livestock keeping and even elementary hygienic measures in this risk-group can considerably reduce the risk of brucellosis (Corbel et al., 2006). For vets, slaughterhouse workers, farm workers, butchers and traders hygiene measures and personal protection is essential during animal manipulation (birthing, manipulation of productions of abortion, slaughtering, butchering) or administration of live brucellosis vaccines (goggles, gloves, etc.). For skin decontamination following exposure to *Brucella*, solutions of substituted phenols, iodophors or dilute hypochlorite solutions are highly effective (Corbel et al., 2006).

The consumption of contaminated food is very important in the transmission of brucellosis in Nigeria as a large proportion of the population consumes raw milk and meat products. Milk pasteurisation is a single measure that will have the biggest impact on prevention of human disease. Whereas meat is unlikely to contain brucellae, consumption of raw or undercooked viscera presents a risk of *Brucella* transmission. Souring of milk and similar methods and drying, salting and smoking of meat are not satisfactory for killing *Brucella*.

The implementation of wide scale regulated milk pasteurisation in Nigeria is unfeasible at this time. Hence the onus of public health authorities should be on the education and sensitisation of populations at risk on the risks of contracting foodborne zoonotic diseases through the consumption of raw dairy and meat products. The approaches to behaviour change should be context-appropriate with an ultimate goal to develop positive, clear steps to empower and support communities to abandon raw milk and meat consumption in favour of boiling and cooking all meat before ingestion. The first step in this process is to identify the knowledge, attitudes and practices which underlie or promote these risky behaviours, to administer a pilot education intervention and to undertake a post-intervention assessment of the success of the intervention in order to identify the main barriers to behaviour change. The education intervention can then be repeated on a wider scale addressing simultaneously the preconceptions, gaps in knowledge and barriers to the sanitary measures being promoted to ensure wider uptake.

10.1.6 Vaccination

Safe and effective vaccines are only available for use in animals. Despite vaccination having been undertaken in occupational-risk groups in Russia and recommended for use in Nigeria by certain authors (Alausa and Awoseyi, 1975), human vaccination is no longer recommended because of the risks associated with the vaccine (hypersensitivity etc.). Vaccination of animals is the single most effective way to both reduce incidence of disease in the animal reservoir and spillover in humans. Vaccines used for this purpose are attenuated live vaccines associated with safety risks and require judicious use in accordance with the following safety precautions: a) they are host species specific hence small ruminant vaccines must be used in small ruminants and cattle vaccines must be used in cattle; b) they may induce infections (milk excretion and abortions, which can be source of human infections) if applied when the animals are pregnant (*Brucella* has a tropism for the reproductive tract during pregnancy due to the production of erythritol); c) they must be handled by qualified personnel (ideally vets) with a maximum of personal protection.

10.1.6.1 Cattle and small ruminant vaccines

10.1.6.1.1 Smooth vaccines: S19 & Rev1

Strain 19 (*B. abortus* S19, US19 or B19) is a cattle vaccine that generates adequate protection in controlled experiments and that has been used in all successful eradication programs in Europe and the US (Nicoletti, 1990). Its main limitations are that subcutaneous vaccination with 5-10 x 10^{10} CFU/animal (standard dose) interferes in S-LPS serodiagnostic tests and can induce genital lesions in vaccinated bulls and abortions if applied during pregnancy (and a small proportion of animals may develop mammary infections and shed the vaccine thereby representing a public health hazard). The vaccine keeps a low degree of virulence for humans but this can be reduced through basic individual protection. Serological interference can be reduced and abortion and milk excretion eliminated through conjunctival administration of the same vaccine at a reduced dose (5 x 10^9 CFU/animal) and/or vaccination of animals less than 4-5 months old (sexually immature animals) (vaccination of animals less than 4 months is useless because of interference with maternally derived antibodies and absence of seroconversion). By this route S19 is also likely to be safe in males but this has not been experimentally confirmed. Conjunctival vaccination has been proven to stimulate adequate protection in adult animals also, with a reduction in abortions and milk shedding to less than 1%. The other advantages of this vaccine are that it is cheap and carries no antibiotic resistance. Strict quality control is essential in production of this vaccine as adequate protection of animals is in equilibrium between inoculation with a vaccine of sufficient virulence so that it stimulates long-lasting humoral and cellular immunity and innocuousness so that it does not cause infection and potential excretion. S19 can also be used in epidemiological situations when cattle infected with *B. melitensis* (as can be the case in spill-over infection of cattle in circumstances of contact with *B. melitensis* infected small ruminants) (Jiménez de Bagüés et al., 1991).

Rev1 is the recommended vaccine for use in small ruminants. Its efficacy has been adequately demonstrated in controlled experiments and in the field (it has been used successfully in the eradication of *B. melitensis* in numerous epidemiological contexts) (Barrio et al., 2009, Blasco, 1997). Unlike S19, the vaccine can be used in

both males and females and is also effective against *B. ovis*. The serological interference, abortifacient effect and milk shedding apply to this vaccine also, and these problems can be largely overcome by using the conjunctival route and vaccinating lambs at 3-4 months old. Operator safety concerns apply also to this vaccine and personal protection is paramount. Additional limitations include resistance to streptomycin and a tendency to dissociate into useless R mutants, which makes quality control protocols even more essential. Rev1 has been suggested as a vaccine against *B. melitensis* infection in cattle but the protective efficacy against *B. melitensis*, innocuousness and safety are not known.

10.1.6.1.2 Rough vaccines: RB51

The interference of smooth vaccines with current tests that detect antibodies to the O-polysaccharide has prompted the development of R mutants (which lack the O-PS) as alternatives. Unfortunately rough vaccines have not resolved the issues of serological interference because animals develop antibodies of O-polysaccharide specificity upon contact with virulent brucellae and thus become serologically positive. Furthermore, R vaccines elicit antibodies to the core-lipid A epitopes exposed in adsorbent assays such as ELISA and FPA. These vaccines are less protective than smooth vaccines (Moriyón et al., 2004).

RB51 is the only *B. abortus* R vaccine currently marketed. Controlled experiments have shown that RB51 is inferior in protection of cattle and that it does not protect sheep against either *B. melitensis* or *B. ovis*. It interferes with ELISAs and FPA, is abortifacient in pregnant cattle and is excreted in milk. There is no accepted criteria for quality control of RB51 and current market prices are high. Resistance to rifampicin is a major drawback as this antibiotic is used for treating human brucellosis. Only very few RB51 infections have been demonstrated (Ashford et al., 2004, Villarroel et al., 2000) but there is little reliable evidence because tests for human brucellosis use *S Brucella* cell suspensions and these do not detect anti R-LPS antibodies. Therefore adherence to biosafety practices should not be abandoned.

Although an infected-vaccinated differentiation makes sense only when test and slaughter policies are applied, RB51 has been used intensively in some developing countries for over 15 years. There is, however, only one case (Azores Terceria

island) where eradication has apparently been achieved (Martins et al., 2009, Martins et al., 2010). It is known that the control measures implemented simultaneously with RB51 in Terceira can by themselves lead to eradication under some exceptionally favourable conditions, like those of islands. Thus RB51 cannot be recommended.

10.1.6.1.3 Protein-deleted vaccines

Another strategy to differentiate infected and vaccinated animals has been the removal of protein antigen. S19 and Rev 1 have been deleted in BP26 (see 2.2.) but the results are not satisfactory because the ancillary test (BP26-ELISA) lacks adequate diagnostic performance (Wang et al., 2009, Grilló et al., 2009, Cloeckaert et al., 2004, Jacques et al., 2007, Salih-Alj Debbarh et al., 1996).

10.1.7 Efficient diagnostic tests and vaccines

Efficient diagnostic tests and vaccines are two sides of the same coin and both are essential in brucellosis control. As explored in Chapter 7 numerous brucellosis diagnostic tools are available, and test characteristics must be carefully considered for use in specific epidemiological settings. Vaccination alters the epidemiological conditions and as such, tests used in this context must be selected accordingly.

10.1.8 Control and eradication strategies

Control of brucellosis cannot be achieved without implementing a vaccination strategy in the animal reservoir. As previously alluded to, control of brucellosis and therefore by default vaccination may however not be appropriate or required for all epidemiological settings in Nigeria. Moreover further evidence is required on the epidemiological peculiarities of brucellosis in settled versus migratory pastoralist herds and the potential existence of endemic stability before specific recommendations can be made on the necessity of vaccination strategies in these production systems. The epidemiological situation in intensive commercial herds bears more similarities to that of Europe or America and hence strategies successfully applied in this context can be extrapolated to the Nigerian intensive/commercial farm context. The section below describes the pre-requisites of a successful control programme and the decision tree that can be applied to select the most appropriate control/eradication strategy.

10.1.8.1 Prerequisites

Efficient diagnostic tests and vaccines are only the tip of the iceberg with regards to the control of brucellosis in ruminants. Successful control is largely dependent on the following factors (Blasco and Molina-Flores, 2011):

1. Definition of the epidemiological unit of intervention. This is not necessarily an administrative unit and can be a geographically defined area (even transnational), a group of villages or farms, etc.
2. A level of organization of veterinary services that makes possible the control of animal movements, the identification of all flocks and herds in the unit and the vaccination of the population in a short time.
3. Active involvement of the community through awareness and education.
4. Economical resources for intervention and, if eradication is the goal, for compensation of culled animals at market value.
5. Well-known herd/flock prevalence and occurrence of human brucellosis by epidemiological unit, including cross-border assessments. Knowledge of the circulating *Brucella* species in the different livestock species involved.

10.1.8.2 Different strategies for control or eradication

Control pertains to reducing prevalence to low levels to minimise the effects of the disease. Eradication refers to the total elimination of *Brucella* from all animal species in the epidemiological cycle. A decision tree has been developed to guide strategy selection for brucellosis control and/or eventual eradication (Figure 128).

Once the epidemiological unit of intervention has been defined, there are three possible strategies (Table 117). There is also a fourth control strategy, which is a compromise between strategy 1 and 2 here below. This strategy is the most complex and consists of mass vaccination and individual identification the first year followed by vaccination only of new replacements in following years.

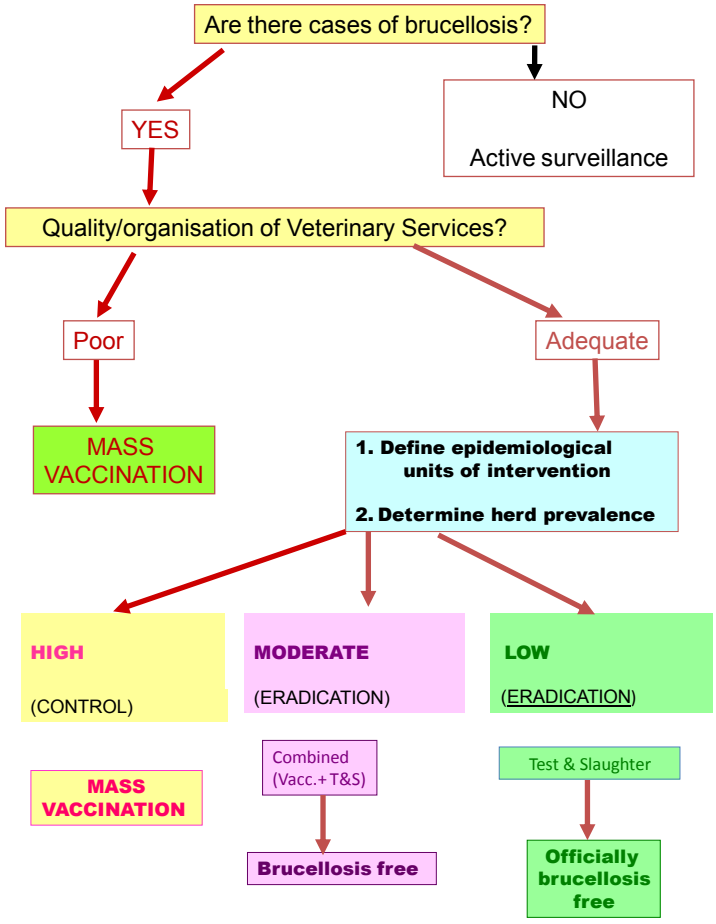


Figure 128 Brucellosis control/eradication decision tree
adapted from (WHO/MZCC, 1998)

1. High collective prevalence (5-10%). Even with good professional organization and economic resources, mass vaccination of all animals (with the exception of bovine males) of all species is the only strategy to control the disease.
2. Moderate collective prevalence (2-5%). Provided the requirements (see above) are met, a combined eradication program based on the vaccination of young replacements (3-4 months old) and test and slaughter in adult animals is recommended to eradicate the disease at medium-long term.
3. Low collective prevalence (≤1%). Provided all the above requirements are met, a test and slaughter program and the ban of vaccination could be recommended to eradicate the disease at short to medium term.

10.1.9 Recommendations for control of brucellosis in Nigeria

The decision to opt for eradication is dictated by the existence of a low universal prevalence and adequate administrative organisation, individual identification and control of animal movements, a substantial budget and the active cooperation of farmers. Nigeria currently does not fulfil any of these pre-requisites and hence control rather than eradication is currently the only feasible objective. The expense of test and slaughter is beyond the resources of veterinary services in developing countries, even when it is justifiable on a cost-benefit basis (Alausa, 1980).

The conditions for control using strategy 2 (yearly vaccination of young replacement stock) can be met in intensive livestock production systems and perhaps sedentary pastoralist herds of Nigeria, but this approach is only practical if the collective prevalence is moderate (between 2-5%). For extensive production systems or intensive farms with a high collective prevalence of disease (5-10%), whole flock/herd (mass) vaccination every 1 to 2 years is the most feasible option (Blasco, 1997). Strategy 2 is an unpractical approach under extensive/nomadic production because it is almost impossible to reach 100% population coverage in these systems. With the continuous reproduction, owners keep replacements all year round and several veterinary visits are required to attain full coverage, which is rarely feasible. This results in a low percentage vaccination coverage being reached and persistence of brucellosis transmission.

The side effects of strategy 1 with regards to vaccination of adult animals have to be accepted by policy makers and livestock keepers. Evidence has shown that vaccination of lactating cows with S19 results in 0.1-1% of mammary infection and milk excretion of S19. Vaccination of pregnant cows has been demonstrated to result in 0.1-1% rate of abortions. Fortunately, field experience demonstrates that conjunctival vaccination with Rev 1 during the last month of pregnancy/lambing/lactation or pre-breeding gives a reasonable safe time-window for vaccination of adults (Blasco, 1997). S19 has less side effects than Rev 1 and they should be minimised following a similar strategy (Nicoletti, 1990).

To be effective, vaccination has to be maintained over time. Once the first mass vaccination has been applied, a procedure to minimize vaccine side effects would be

to cover only the young replacements yearly but the above-summarized difficulties make this unrealistic. The annual replacement for ruminants in extensive breeding systems usually ranges between 15 to 25% so that one year after the first mass vaccination, 15-25% of the population should be new, unvaccinated and susceptible to brucellosis. However, it is improbable that the infection be maintained and extended by transmission to this relatively low percentage of unvaccinated replacements because most would not be sexually mature, and thus not in the period of maximal risk of excretion and spreading (pregnancy). Experience with S19 shows that adult vaccination is a practical way to control the disease, even without the removal of reactors (Nicoletti, 1990). These observations indicate that skipping mass vaccination in the second year is acceptable. Two years after the first mass vaccination, the population would include 30-50% of unvaccinated animals many of which would be sexually mature or pregnant, then in the critical risk period. A cost-effective mass vaccination strategy could be repeating mass vaccination every two years, always during the late lambing or calving and pre-breeding periods.

The epidemiological unit to be targeted also refers to the animal species. Evidence would suggest that cattle are the most important source, reservoir and are most affected by brucellosis in Nigeria (Esuruoso, 1979). When outbreaks in humans have been detected they have been in close associations with cattle. Control proposals should be directed primarily at disease in cattle. Bacteriological evidence suggests that small ruminants are a spill-over host for *B. abortus*. In situations of co-rearing or co-grazing of cattle and small ruminants, it may be appropriate to vaccinate small ruminants as well as cattle. Failure to eliminate the disease from sheep and goats could enable a reservoir of *B. abortus* to establish in these species and be able to re-infect cattle should the vaccination programmed be stopped prior to the natural phasing out of infection from the small ruminant reservoir.

Strategy	**1**	**2**	**3**
Collective prevalence	High (5-10%)	Moderate (2-5%)	Low (≤1%)
Strategy	Mass vaccination (including adults and young replacements) every 1-2 years (except bovine males)	Yearly vaccination of young replacements and test and slaughter in adult animals	Test and slaughter and ban of vaccination
Objective	Control (reduce prevalence to low levels)	Eradication (brucellosis free status)	Eradication(brucellosis officially free status)
Requirement for organised veterinary services?	NO	YES	YES
Other requirements	NO	• Individual tagging • Animal movement controls • Funds for compensation • Safe source of health replacements	• Individual tagging • Animal movement controls • Funds for compensation • Safe source of health replacements • Ability to test 100% of animals in a short time • Ability to slaughter infected animals in few days
Safety	HIGHER RISK More risks of abortion and milk excretion if animals vaccinated during pregnancy (can be reduced by vaccinating during ideal window of opportunity to minimise side effects which is a few weeks during breeding/late lambing or calving/lactation)	LOWER RISK (vaccination of sexually immature animals eliminates risk of inducing abortions and milk excretion)	SAFE
Serological interference	HIGHER as vaccinating adults (can combine vaccination with more specific diagnostic tests such has DGD-NH to minimise vaccinal positives)	LOWER as vaccinating young animals	Depends on when ban on vaccination rolled out Requires judicious choice of serological tests as most tests would lead to over-condemnation rates
Other disadvantages	Must alter to strategy 2 before serological interference issue resolves enough to enable T&S	• Impossible to reach 100% coverage in extensive/nomadic systems • In situations of continuous reproduction owners can keep replacements all year round and several veterinary visits are required or a low % of vaccination coverage is reached • Requires judicious use of serological tests	• Overkilling of healthy animals caused by lack of specificity of serological tests (due to *Y. enterocolitica* O:9 etc.) • Premature banning of vaccination is most frequent error (best indicator of brucellosis-free status is absence of human disease)
Timeframe to immunise total population (with annual replacement rate of 20%)	FASTEST Whole population vaccinated with single intervention (however must remember that in 2 years 40% of population would be unvaccinated)	5-10 years (depending on animal species and husbandry system)	SLOWEST as usually must pass through strategy 2 before prevalence is low enough to phase out vaccination and proceed to T&S only
Cost	CHEAPEST Vaccine and operative costs only	MEDIUM Vaccine, operative costs and compensation funds	MOST EXPENSIVE Huge financial commitment to operative costs and compensation

Table 117 Three strategies of brucellosis control/eradication

10.1.10 Untangling the evidence

There are too many gaps in knowledge to accurately define the epidemiological units of intervention and therefore make appropriate recommendations for control. It is a priority to address these gaps to justify control in each specific epidemiological context and pilot small-scale interventions, before wide-scale, coordinated template control strategies of proven efficacy can be proposed.

If emergence of brucellosis in situations of sedentarisation of previously nomadic pastoralist herds proves to be correct then the message to policy-makers is simple and appealing. Control measures should be primarily focused in the settled intensive or semi-intensive herds where the disease is likely to exist at higher levels and where the animal productivity is likely to be affected. The migratory pastoralist herds (where vaccination strategies are more difficult to undertake), should, however, be left alone as chronicity in those herds means that although brucellosis exists, few abortions occur and the disease is unlikely to have a marked impact on productivity. These herds do, however, constitute a reservoir of disease, therefore vaccination of settled herds that have contact with nomadic animals must be continued for as long as a reservoir of disease exists in the nomadic system. Vaccination in Nigeria will be necessary for as long as brucellosis persists in the nomadic pastoralist herds. This means moving to eventual eradication (through vaccination of young replacements and test and slaughter of reactors) must ONLY be considered once the brucellosis prevalence in the entire brucellosis reservoir (intensive settled, semi-intensive settled and extensive migratory) has been reduced through vaccination. The financial commitment of country-wide mass vaccination to achieve eradication versus a more targeted and cost-effective approach of reducing the disease prevalence in livestock systems where productivity is affected the most, seems more realistic and justified.

Before control recommendations can be made, the following should be addressed:

1. Should there be different control strategies for the extensive nomadic versus the extensive sedentary and intensive systems?

2. Is a control strategy for the Fulani extensive system critical to safeguard the *Brucella*-free status of intensive farms?

3. Is the Fulani hypo-endemic reservoir of brucellosis and the existence of 'endemic stability' in this system a justification for not interfering in the absence of human disease and minimal impact on animal productivity?

4. Is it therefore more important to focus vaccination measures on the intensive livestock production system should this population come into contact with the pastoralist reservoir?

A 'one-size fits all' control strategy, that can be applied indiscriminately across all regions, species and production systems, does not seem appropriate for Nigeria based on the evidence available. Rather interventions need to be adapted to the extensive versus the intensive system, hot spot areas of emergence versus hypoendemic areas, taking into consideration variations in socioeconomic determinants of disease across different geographical and political zones. And recommendations should be based on what is economically and practically feasible for the Nigerian context.

With the existence of political barriers and gaps in knowledge as to the real extent of the brucellosis burden, the prospects for control seem bleak.

10.2 Brucellosis control in the KGR

In this section data on attitudes of the KGR community to brucellosis control measures is presented. In the second part brief recommendations about control for brucellosis are made based on the evidence presented in Chapter 8.

10.2.1 Attitudes to brucellosis control measures

10.2.1.1 Materials and methods

Attitudes to brucellosis control measures and potential barriers to control were assessed through questionnaires and FGD. The questionnaire was administered as part of the October survey to 80 households, and the FGD 'From cow to mouth' (see appendix) was undertaken with groups of men and women (see Chapter 2). The questionnaire and FGD guides are included in Box 5 and Box 6 respectively.

BOX 5-FGD question prompt on barriers and attitudes to brucellosis control

I told you earlier that things can be done to prevent people catching illnesses from the milk of their cows. I will now go through this. To stop you and your family catching sickness from milk, the milk should be BOILED and stirred for 5-10 minutes. BOILING is when the milk bubbles and froths on the surface. STIRRING is necessary because it allows the heat to get to all the milk. The HEAT is the thing which will kill the bugs in the milk and make it safe for you to drink. To be fully protected, a person must ONLY drink boiled milk or eat milk products made from boiled milk. Protection does not work if some milk is consumed raw and some is consumed boiled, even if the raw milk accounts for only a small proportion of the milk consumed.

I would now like to know your opinions about an education campaign surrounding the above message which we are hoping to disseminate to the KGR community.

1. Do you have any thoughts on how to best bring this message to the KGR community.

2. Do people like pictures? Can people read? Do they like workshops? Or would people like to learn about these things through the radio

3. Can you think of any reasons why people may not want boil all of their milk? Do you think, for example, that it would take too much firewood?

4. Do you think that this message would be popular? If not, why not?

5. Do you think that people would actually do this long term? If not, why not?

BOX 6 – Questionnaire questions on attitudes to brucellosis control

1. *We would like to teach people in the KGR about things that they can do to protect themselves and their families from catching diseases from animals.*
    a. How do you think we should do this?
2. *One of the things we will recommend is for all milk to be BOILED and stirred for 5-10 minutes. BOILING is when the milk is so hot that it bubbles and froths on the surface. The heat will kill the harmful bugs in the milk and make it safe to drink.*
    a. How do you think people will feel about this?
    b. Can you think of any reasons why people may not want to do this? (for example, would they have enough firewood?)
3. *Another way to protect people from disease is to vaccinate the animals. This also protects the animals from catching diseases.*
    a. How do you think people would feel about this? Would they have any apprehensions or worries about the vaccination?
    b. Do you think people would be willing to pay for the vaccine?
4. *Products of abortions and afterbirths are also a way that people and animals become infected. People should protect themselves by not touching these directly and they should protect their animals by destroying the material.*
    a. Can you think of ways that people can protect themselves from touching aborted material or afterbirths directly?
    b. Can you think of ways that people can destroy these materials?
    c. How can we convince people that these things are important?
5. *Slaughtering and butchering of animals is another way that people can catch diseases from animals. They should protect themselves to lessen the chance of catching disease.*
    a. Who practices slaughtering of animals in the KGR?
    b. How would these people feel about having to spend more money on things like gloves OR using the plastic bags which bread comes to protect them from disease?
    c. How can we convince these people that they should protect themselves?
    d. Can you think of anything that they could do to protect themselves?

10.2.2 Results

10.2.2.1 Perception of best approach for health messaging

The questionnaires demonstrate that individual household visits are the preferred approach for dissemination of health messages and community education (Figure

129). The second ranking strategy of preference refers to the dissemination of health messages to community leaders, religious leaders or healthcare officials who can then disseminate the information to the rest of the community. Mosque announcements and community meetings were also mentioned. Use of radio or pamphlets were the two least popular answers.

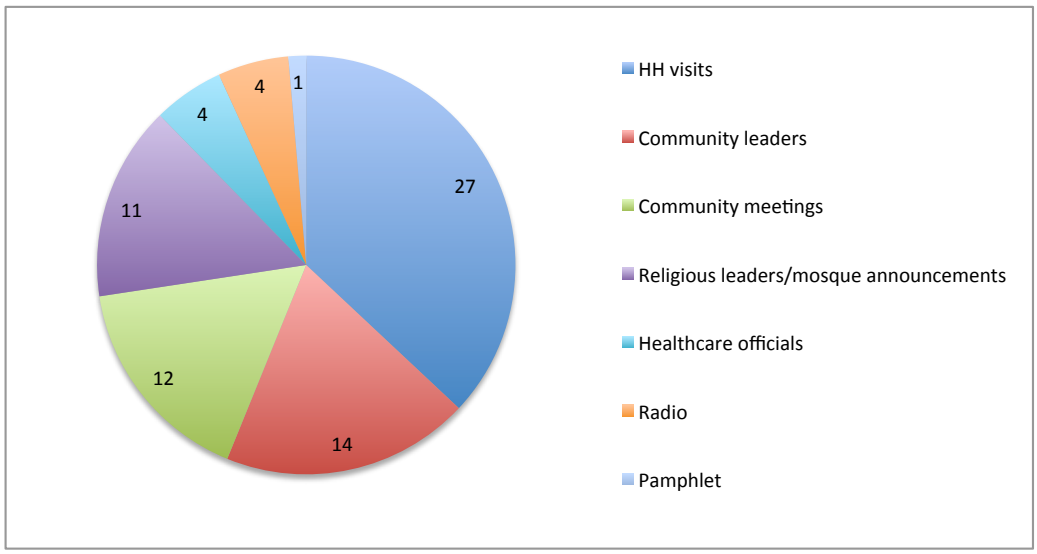


Figure 129 Perception of best strategy for health messaging

FGDs showed that women preferred the use of information booklets (with pictures and written information below) or seminars to pass on information. They felt that radio was a good medium for information. The men were categorical about the method to employ and stated that: '*we have leaders, and we always obey and respect them; if you go through our leaders people will follow; there is no other way.'*

10.2.2.2 Attitudes to consumption of boiled milk exclusively

Figure 130 summarises the number of answers given on how people feel about being advised to boil their milk. The vast majority stated that people would 'accept' such advice. However, the biggest barrier to change was considered to relate to tradition, superstitious beliefs or taboos. Many of the respondents alluded to boiling of milk going against the traditional beliefs of certain Fulani clans, especially the Yabaji clan or Bororo Fulani (these are Fulani still engaging in a traditional pastoral way of life). The household head from a Yabaji household stated: '*most of our people will not boil milk, it is our tradition'*. The superstitious beliefs behind the reticence to boil milk

are illustrated in the following answers, and refer mostly to health advantages for people who drink milk raw but also to the negative impact which milk boiling will have on the cattle itself: *'Boiling destroys most of the nutrients in the milk'.*

'Unboiled milk enhances our ability to walk and run after our animals'.

'We believe that boiling pains the cow the milk came from by paining the teat and then we get less milk'.

'Boiling diminishes our wealth and the performance of our animals'.

Some respondents were of the opinion that lack of knowledge of the dangers of taking raw milk (ignorance) and illiteracy may also constitute barriers to behaviour change. Other respondents refused to commit to giving an answer and simply stated that they had 'personal' reasons for not agreeing to boil milk.

The FGD with women revealed practical barriers behind milk boiling, including: *'Children go out on migration with cattle and take raw milk, how do you prevent that? Young boys who go to the bush will continue taking raw milk from cows as it is the only source of food for them.'*

'There is no way of controlling the heat on the wood fire, if we leave the pot on the fire the milk boil over therefore it is hard to us to boil for 5-10 minutes.'

'Young children like the taste of raw milk therefore they will continue to take it even if we have enough food.'

Women confirmed that certain people had superstitious beliefs about milk boiling: *'Some people will not boil milk because believe this will hurt the dam and it will dry up the milk.'*

Men also shared practical reasons for difficulties to boil milk: *'There are instances when you are out with cattle and it will rain all through the day and you cannot make a fire, in that situation you will only survive on fresh milk'.*

Men gave a realistic view of the difficulties of behaviour change and the lack of evidence to convince them that they should boil milk. '*Change is very difficult, it is something that will be gradual and will happen over time, but for now we will not change. We have been living on raw milk without any problem, so we will not change our behaviour. We have been doing this for centuries and have been fine.'*

One man said: *'I think you are confused. In your country you boil the milk because you have problems we do not have here'.*

The men also shared advice on how to ensure sustainable change: *'The message of boiling cannot be preached just once; it must be a continual process. It will be a LONG PROCESS. People will keep getting enlightened and will accept change gradually and there may come a time when all that is said about boiling will be here to stay. When the old ones are phased out, the young ones will embrace it.'*

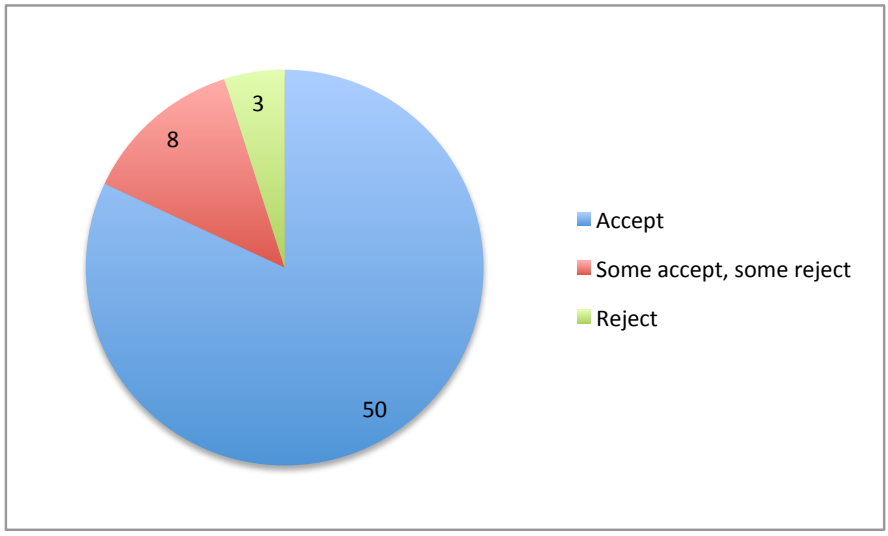


Figure 130 Perception of predicted acceptance of community towards being advised to boil milk

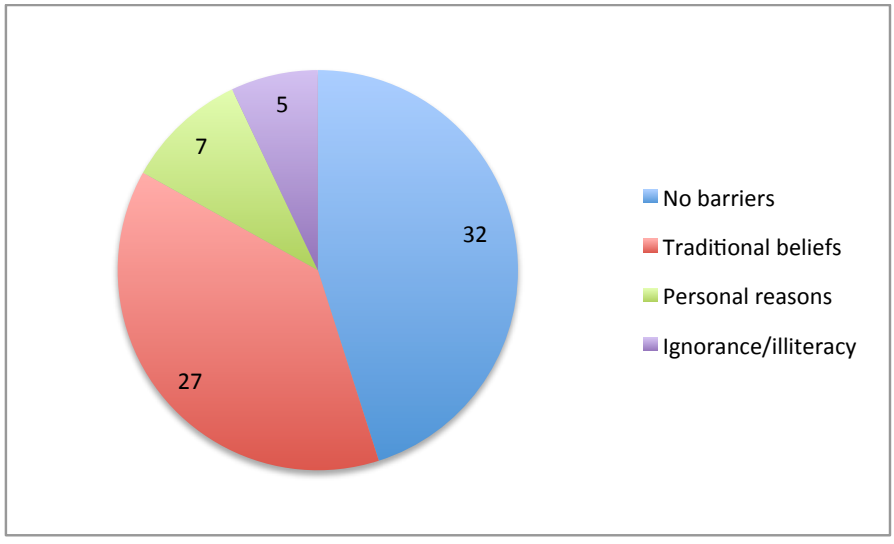


Figure 131 Perception of barriers to boiling of milk

10.2.2.3 Attitudes to vaccination

Respondents were unanimous in their response to how the community would feel about vaccination of livestock. They stated that this approach would be '*100% accepted* ' that they would be *'eager to have vaccines',* and that they *'welcomed the idea because prevention is better than cure'* and were *'aware of the advantages of vaccination'.* All respondents also confirmed that they would be willing to pay for a vaccine, but some emphasised that could only do so if the cost was not high.

10.2.2.4 Attitudes to handling products of abortion and birthing materials

When asked about strategies that could be employed for people to protect themselves during handling of birthing materials or products of abortion, respondents suggested covering their hands with plastic bags/cloths/leaves or using sticks to carry the material. To destroy/remove the material, respondents mentioned burning, burying or discarding far away in the bush.

10.2.2.5 Attitudes to slaughtering and butchering

The questionnaire showed that animal slaughtering for household consumption is undertaken by senior male household members or by the KGR butchers. Some may slaughter at home and then ask for the butchers to do the butchering. Animals for public consumption are slaughtered by butchers or religious leaders (chief Imam). Butchering of such animals is undertaken by the KGR butchers. Butchers, do the bulk of the animal slaughtering and butchering in the KGR, but since any man can practice animal slaughtering, education campaigns should target all males.

Suggestions of protection strategies during slaughtering included holding educational meetings with butchers to enlighten them of the risks and ways in which they can be reduced. When quizzed about how butchers could protect themselves, people mentioned the use of gloves, boots and general protective wear. One man even stated that: *'With the sensitisation the idea that butchers should protect themselves will be welcome and the community can pay for their protective wear'.*

10.2.3 Recommendations for brucellosis control in KGR

Brucellosis control is based on sanitary prophylaxis in humans and animals and use of animal vaccines. The suitability of these strategies for KGR is discussed and recommendations made based on what is known about the KAP of the KGR community for control measures and the epidemiology of brucellosis in KGR.

10.2.3.1 Sanitary prophylaxis

Epidemiological surveys showed evidence of *B. abortus* in cattle in KGR. Infection in small ruminants is less certain but serological evidence suggests potential spill-over from the cattle reservoir. To reduce transmission of *Brucella* between cattle and from cattle to sheep and goats, recommendations should incorporate the following:

- Avoid purchase of animals, especially bulls (and if do so ask about abortion history and check for hygromas);
- Avoid sharing males for mating with females of other herds;
- Avoid sharing females for mating with males of other herds;
- Avoid grazing with the animals of other herds;
- Avoid going to watering points at the same time as other herds;
- If an animal is about the calve, allow it to distance itself from the rest of the herd so it can calve in isolation;
- Remove products of abortion or birthing materials to prevent animals having contact with these;
- Sell animals with hygromas and infertile males or females for slaughter rather than trade.

Despite the serological picture for humans in the KGR suggesting that humans are not infected with *Brucella*, the presence of a *Brucella* reservoir in cattle is evidence enough to incorporate recommendations on how to prevent animal to human transmission. These recommendations should include:

- Boiling of all milk for human consumption for 5-10 minutes;
- Protection during handling products of abortion or birthing materials;

- Protection during slaughtering and butchering of animals.

10.2.3.1.1 Approach for health education and messaging

To encourage animal and human sanitary prophylaxis community education on what brucellosis is, and how it can be spread should be undertaken with health messaging on how transmission between animals and from animals to humans can be prevented.

10.2.3.1.1.1 Who?

The KGR community is patriarchal in nature, and health messaging should firstly go through the community leaders, including the district head, the Ardos (village chiefs) and religious leaders. Involvement of healthcare officials is also paramount. Dissemination of an education campaign respectful of the natural hierarchy of the community is key. The questionnaire results suggest, however, that the majority of KGR community members would like to be briefed through household visits or during community meetings. The reason for this is that information disseminated to community leaders is not always effectively communicated to community members. Hence a grassroots approach to complement the top-down approach would be necessary to ensure good health message dissemination within the community.

With regards to targeting of messages to specific segments of the community, this depends on their engagement in various risk practices. Women process the milk within the household and should be the main recipient of the message to boil all household milk. Children are given a lot of raw milk within households and sensitisation at school on risks involved and importance of boiling of milk would also be advocated. Young men are the ones sent on transhumance and who rely on the drinking of milk for survival, and they should also be briefed on the importance of boiling milk before ingestion. Men predominantly deal with birthing and slaughtering of animals and messaging should incorporate risks and ways to prevent them. The butchers of KGR, who are Hausa rather than Fulani, should be targeted and educated in ways in which they can protect themselves to minimise transmission.

10.2.3.1.1.2 What?

The respondents showed a preference for verbal communication of messages either at individual or household level or at larger scale community meetings. The radio

was also mentioned as a good medium through which to communicate ideas. One thing to bear in mind is that a large proportion of the KGR community is illiterate, hence printed material should rely more on pictures rather than words. An education campaign would ideally firstly involve briefing of healthcare officials on the specific health messages. These community members would then be involved in the messaging of community leaders (ardos, religious leaders).

Messaging to household is more challenging. Household visits are time-consuming and costly. Messaging to men could be achieved through mosque announcements delivered by Imams. All men attend the Friday prayer and hence all male members of the community would be exposed to the message. There are various mosques within the reserve to cater for different blocks, and all mosques should be targeted.

Targeting of butchers would be easy as they are based in the centre of the reserve in Tampol and meetings could be organised in this location, as they were for FGDs.

Targeting of children could be achieved by incorporating health messaging in to their Koranic school teaching (although this may not be approved by Imams). All children in the KGR attend Koranic school, however not all children attend formal government provided education and hence messaging undertaken at these schools would reach only a segment of KGR children. Imams and teachers could be briefed on the health messages so as to deliver the messages themselves.

Health messaging of women probably poses the most challenge. Women do not attend prayers in the mosque and the community does not generally approve women being summoned for meetings. The mouthpiece of women in the KGR is the emancipated ‘rise of dawn’ co-operative. Meetings could initially be organised with this group. Women within KGR could be educated through pamphlets with messages communicated with pictures due to high illiteracy rates. Radio programmes may also be a solution but generally radio listening is a male pastime rather than a female one.

The language of choice for education of the KGR community members is Fufulde and Hausa for the butchers.

10.2.3.1.1.3 When?

It is important to plan the education campaigns for June and November, two times of the year when the least number of people in KGR are on transhumance.

10.2.3.1.1.4 For how long?

Interviews with men emphasised the importance of repeating the health messages over time. The best way to evaluate when to stop health messaging is to assess the impact of the education campaign with regards to behaviour change and knowledge. Comprehensive data is available on the baseline practices and knowledge of KGR pastoralists, and their knowledge, behaviour and practices could be assessed after each phase of education to monitor progress.

10.2.3.1.1.5 How much does it cost, who pays and who rolls it out?

An accurate assessment of the cost of such an approach is beyond the scope of this thesis, but the budget for such a scheme is likely to be minimal. Costs should be estimated and presented to the National Livestock Development Project who are committed to developmental programs in Grazing Reserves (NPFS, 2013). The National Veterinary Research Institute, who have been involved in all aspects of brucellosis research in the KGR and have an 'extension office' service for nomadic education at their disposal should coordinate this health messaging campaign.

10.2.3.2 Vaccination

There are three main questions concerning vaccination in the KGR is: 1) Is there a need to vaccinate? Do the pros outweigh the cons of vaccination in this context?; 2) What is the best vaccination approach?; 3) What are the barriers to vaccination and can these be overcome?

10.2.3.2.1 Justification for vaccination

Herd prevalence is important from the perspective of control. In March herd prevalence was found to be 4.8% and in June the prevalence was found to range between 17.5 and 27.5% (according to different interpretation criteria, see Chapter 8). The moderate-high herd prevalence would suggest that vaccination in the KGR is indicated. The counter argument is that a 1% individual prevalence represents such a

low burden, which in the absence of human disease may not justify the costs of rolling-out a vaccination campaign. The advantages of vaccinating animals in the KGR would be a slight increase in animal productivity, but this has to be balanced with the side effects of vaccination, which include vaccine-induced abortions if animals are vaccinated during pregnancy (even through the conjunctival route) and the risk of potential human infections with vaccine strains in such circumstances. Another advantage of vaccination is that if the predictions about a potential increased brucellosis transmission in the face of mass-immigration into the KGR are correct, this could prevent brucellosis prevalence from further increasing (and for the disease to potentially emerge in the human population as a result of increased challenge from infected cattle). The evidence for this remains tenuous, and so this prediction would need to be substantiated with more evidence to recommend vaccination at this time.

10.2.3.2.2 Implementation of mass-vaccination

Whole-herd (mass) vaccination is the only feasible strategy for the KGR, for reasons discussed in 10.1.8. Field experience demonstrates that conjunctival vaccination with Rev 1 during pre-breeding, late calving and lactation provides a reasonably safe opportunity for mass vaccination. The side effects of S19 are more limited than those of Rev1 and they should be minimized following a similar strategy.

Follow-up must include complementary serological testing. In the every-two-year mass-vaccination strategy, a careful selection of the frequency of testing and the test itself is necessary because the serological background of mass vaccinated animals living in an infected environment it is not easy to interpret. Even when applied conjunctivally, the serological response induced by vaccines in adult animals is of higher intensity and duration than that induced in young replacements. Although protected, vaccinated animals produce anamnestic responses upon contact with field brucellae. Thus, a follow up requires the use of an appropriate test, and under these difficult conditions where infected and vaccinated animals coexist the NH tests (DGD and AGID) have been proved useful (Díaz et al., 1979, Jones et al., 1980).

10.2.3.2.3 Barriers to vaccination in the KGR

The main barriers to vaccination are the following: 1) No reliable veterinary service to administer the vaccine; 2) Difficulty to maintain the cold chain due to absence of electricity; 3) No predictable calving season; 4) Practice of transhumance during dry and wet season mean that proportion of community may be away and their animals cannot be vaccinated; 5) Poor quality of local vaccine and reticence of veterinary services to use imported vaccines; 6) Even though people are very willing to vaccinate, combined cost of vaccine and operative costs are likely to be too high for the community to self-finance such a vaccination campaign; 7) Lack of political will for government to subsidise vaccination campaign.

10.2.3.3 Conclusion

In the presence of low individual brucellosis prevalence, the cost of vaccination in cattle and/or sheep may outweigh the benefits of improved animal productivity in the absence of costs averted due to reduction of human disease. Other human and animal diseases may be having more of an impact on the KGR and their control may present more cost-effective solutions to improved community health (see Chapter 11).

11 Chapter 11 Livestock and human health in the KGR

11.1 Introduction

Disease ranking can be used to channel limited resources towards priority health issues and achieve maximum impact in terms of reduction of burden of disease and improvement in animal and/or human health. Formal quantitative methods have been applied for disease prioritisation on different scales (i.e. country-wide, regional or even global). The DALY, for example, ranks human diseases in the global burden of disease study, and cost-effectiveness of interventions to control disease can also be used as criteria to advocate for prioritisation of zoonoses at the global health agenda (Fox-Rushby and Hanson, 2001, Murray, 1994, Roth et al., 2003) (see Chapter 1).

To have awareness of how communities tackle disease and seek health is fundamental for the development of context-appropriate recommendations for disease control. If attitudes and practices surrounding treatment and prophylaxis are known, disease control recommendations can be prioritised, sometimes based on relatively small changes that are easy to implement and are more likely to be accepted. With this approach, prioritisation of disease control is not based only on burden ranking but also on ranking of practicability, feasibility, affordability and acceptability of the actual control and prevention measures (Obrist et al., 2007, Zinsstag et al., 2011a, Zinsstag et al., 2011c, Schelling et al., 2007b). The rationale is not necessarily to implement novel treatment or prophylactic regimes, but to optimise current protocols and regimens. What are people already doing to tackle human and animal disease and how can this be improved to get better results?

This chapter seeks to critically evaluate current approaches to disease control and treatment practice in cattle and small ruminants in the KGR and examine health-seeking behaviour for fevers in humans.

Evidence suggests that the brucellosis burden in cattle is low in KGR despite herd prevalence levels being moderately high. Human brucellosis was absent in KGR despite widespread consumption of raw cattle milk and engagement in other “risky behaviours”. For this particular community brucellosis may not be a ‘priority’ disease in terms of a ‘dual’ human and animal burden. Given the low risk to

communities from brucellosis it is pertinent to consider which animal and human diseases are perceived to be priorities by the community and health and veterinary service stakeholders and providers.

In March and June 2111 surveys were undertaken which incorporated data collection for trypanosomiasis, helminth/protozoa infections and bovine tuberculosis (June only) in the same population of cattle that permits comparison of empirical data with perceptions of disease from the KGR community. For small ruminants, only empirical data for brucellosis were collected. Questionnaire data on household reports of symptoms experienced and community disease perception is used to make inferences of potential diseases of importance to small ruminant health in KGR.

In this chapter a qualitative approach to prioritisation was employed, incorporating disease ranking according to perceived community priorities. KGR community members were interviewed on their experience, perception and attitudes to fevers (fever as a main symptom of human brucellosis). A priority was to establish 'whether fevers were a health concern for the KGR community?' and 'if fevers are not due to brucellosis infection, what diseases are perceived responsible for fevers in KGR?'.

This can be aligned with KGR-specific prevalence data where available and household expenditure on chemotherapeutics and prophylactics. Since only empirical epidemiological data on human brucellosis were available, key informant interviews with individuals working in the health sector were used to inform ranking of fever-inducing aetiologies as defined by KGR community members. The amount of spent by households on specific diseases may be proportional to the perceived importance of a disease (spending money on prophylaxis or treatment for a disease is likely to signify that this disease is a priority issue at household level). Since this approach is inherently biased (purchase of drugs being affected by availability, accessibility and affordability) the limitations and merits of this approach are considered.

11.2 Materials and methods

Data on livestock health priorities, approaches to disease control and household expenditure on animal disease control were collected through questionnaires administered alongside the March and June 2011 surveys, followed by key informant

interviews and FGD (Table 118). Cattle sampled in March and June 2011 were screened for helminth /protozoal infections, trypanosomiasis and BTB.

Data on community burden of fevers and household perceptions and practices related to fevers were collected during October 2011. KII and FGDs relating to human health and health seeking behaviour were also collected (Table 118).

Theme	*KII/FGD*	*Target*	*No.*	*Sex*	*Age*	*Location (block)*	*Period*
Animal Health							
'Hanta' (fluke)	FGD	Pastoralists	8	M	NS	KGR	March
Approaches to disease control	FGD	Pastoralists	8	M	NS	KGR	March
Veterinary drugs for sale and prices	KII	Vet drug seller KGR	1	M	NS	KGR	March
Livestock health problems seen at sale or slaughter	FGD	Butchers and traders	5	M	NS	KGR	March
	FGD	Butchers	12	M	22-45	KGR (1)	Oct
	FGD	Traders	8	M	30-71	KGR (1, 2, 4 & 5)	Oct
Animal health issues, BTB and Hanta	KII	AVO	1	M	52	Gov vet clinic, Kachia	Oct
	KII	PO	1	M	35	Project office	Oct
	KII	PO	1	M	35	Project office	June
Human health							
Common diseases and fevers	KII	Dr Jamo, MD	1	M	65	Private Clinic, KGR	Oct
	KII	CHT	1	F	28	NGO clinic, KGT	Oct
Health-seeking behaviour	FGD	Housewives	10	F	20-42	KGR (2)	Oct
	FGD	Pastoralists	9	M	52-80	KGR (2, 3, 4 & 5)	Oct

Table 118 Summary of FGDs and KIIs undertaken during the three surveys including target group, and number, age, sex and block of origin of participants

(NS- not specified M- male, F- female, AVO- Area Veterinary Officer, PO- Project Officer, MD- Medical Doctor, CHT- Community Health Technician)

11.3 Results

11.3.1 Livestock health

11.3.1.1 Cattle health priorities

The questionnaire administered in March 2011 requested respondents to list their main cattle health problems and to rank them in order of severity for their household (Figure 132). The breadth and depth of knowledge into diseases affecting cattle was remarkable bearing in mind that this is a predominantly illiterate community.

Answers comprised a combination of disease conditions and symptoms (respondents may observe the symptoms but may not have the knowledge to attribute clinical signs to specific disease). Traditional nomenclature and terminology may correspond to western systems, but indigenous veterinary knowledge can be uniquely structured and care is needed in interpreting traditional diagnosis (Mariner, 2002). Hanta, for example, according to western veterinary interpretation has two separate aetiologies and diagnoses. Indigenous animal health knowledge in this pastoralist community was diverse and, as previously observed by Mariner (2002):

"*Pastoralists and agropastoralists have a rich and detailed knowledge about significant health problems affecting their animals.*"

'Hanta' (*faciola*/clostridial disease) ranked as the most commonly mentioned disease, followed by 'samore' or trypanosomiasis (Figure 132). Bakale or brucellosis was listed third; followed by 'boru' or foot and mouth disease (FMD), 'fufu' or contagious bovine pleuropneumonia (CBPP), goli or parasitic gastroenteritis (PGE), 'kirchi' or dermatophylosis, 'sefa' or anthrax, 'baba' or lumpy skin disease (LSD) and blackquarter. Ingestion of plastic bags was also considered a problem.

Symptoms most commonly mentioned included otitis/ocular discharge, symptoms related to poor nutrition including pica, stunted grow and starvation, and 'rough hair coat' which are a general signs of ill-health in animals.

The KGR project officer confirmed hanta as the number one problem for the KGR community and reported seeing more than 30 cases per month. Butchers and traders confirmed hanta as the priority disease issue "*as they have to discard the liver*" and estimated observing 10-20 cases per month.

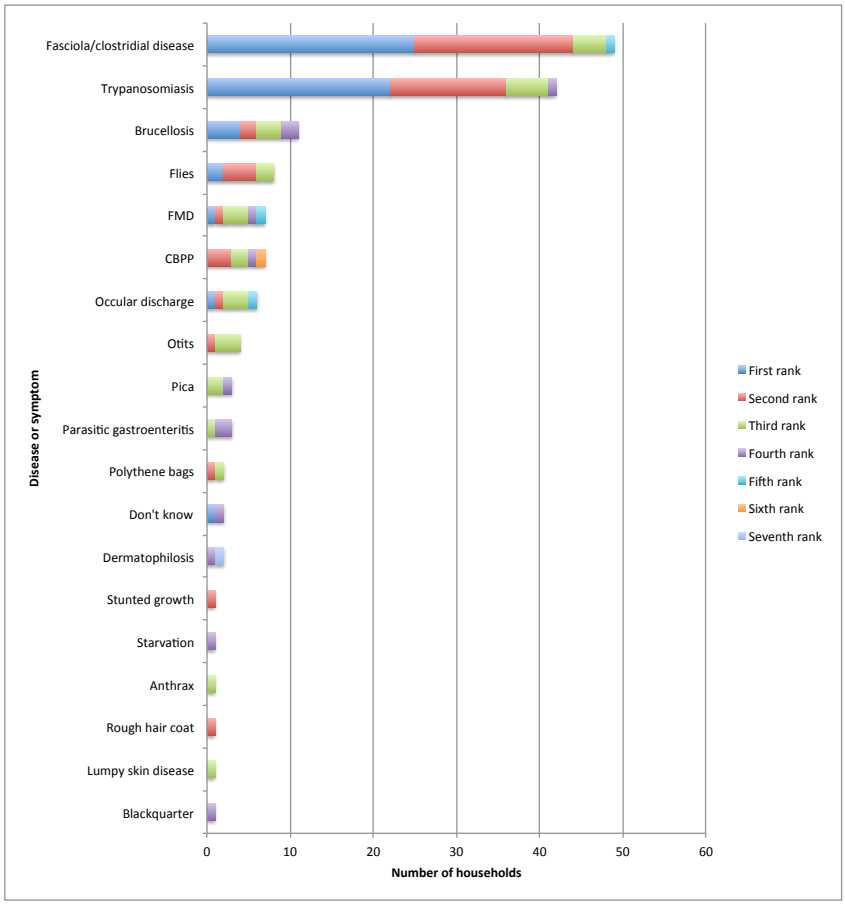


Figure 132 Number of households ranking various diseases and symptoms as number one, two, three, four, five, six or seven priority for cattle health, March survey

11.3.1.2 Small ruminant health priorities

Small ruminant health in KGR was considered less of a priority both from the type and quality of answers provided by respondents. Small ruminants have a lower cultural and economic value in Fulani communities and knowledge of small ruminant disease was more limited than that of cattle.

The disease perceived to be most important was ‘Hanta’. Peste des petits ruminants (PPR) was the second most commonly mentioned disease condition (Figure 133). Most respondents described the symptoms of PPR but claimed they did not know the name of the disease, some respondents referred to the condition as ‘dumaral’ and some as contagious pleuropneumonia. The PPR ‘combined’ category describes a common observation: respondents reported having lost a large proportion of the sheep flock to a wet season disease which started off with respiratory signs closely

followed by scouring, fleece loss and then death. The differential diagnosis that fits this highly contagious condition with a high case fatality is PPR. Analysis of small ruminant death data revealed that households reported a large number of small ruminant deaths. The mean household death rate (number of individuals that died in HH/flock/herd) was high at 44.4 and 46.2% for sheep and goats respectively.

The large number of deaths experienced in sheep and goats in the KGR was discussed in FGDs. Some participants felt it was a problem associated with biting flies. Others considered it was due to open housing whereby sheep are exposed to the elements (wet environment with unsanitary build up of urine and faeces). During the wet season small ruminants are restrained with ropes and pegs to prevent them to straying into crops and their grazing is restricted to the radius of rope. Close contact between sheep at a time when climatic conditions are poor may also have promoted spread of the ovine rinderpest virus.

Other conditions ranked as small ruminant health priorities follow those mentioned for cattle and appear to be a transposition of cattle health knowledge.

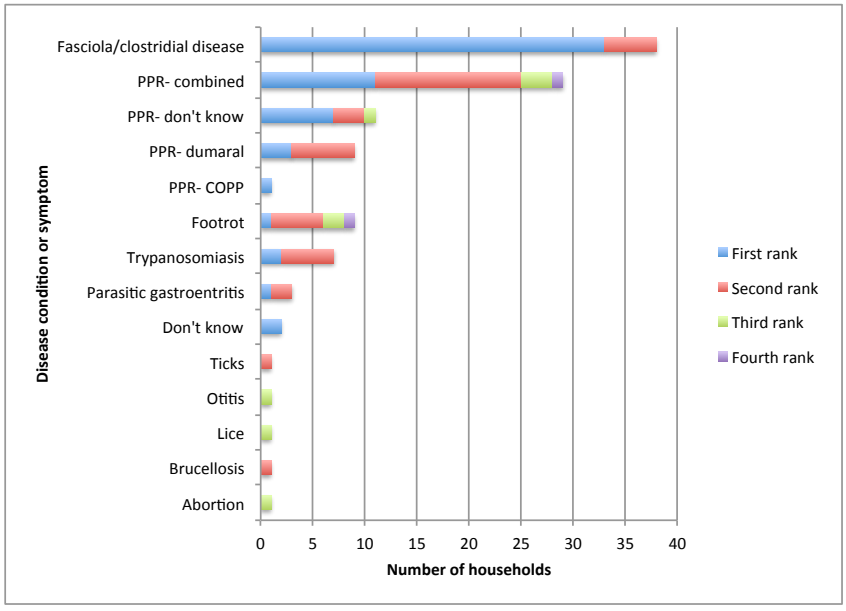


Figure 133 Households ranking diseases and symptoms as number one, two, three, four priority for small ruminant health, March 2011

11.3.1.3 Differential burden in term of prevalence of disease in cattle

Disease burden is the impact of a health problem as measured by financial cost, prevalence/mortality/morbidity, or other indicators. In this section we consider prevalence of disease and in subsequent sections frequency of drug use and household expenditure on animal health.

The prevalence of helminth infections/coccidiosis, trypanosome infections, bovine tuberculosis and brucellosis in KGR are shown in Table 119, Table 120, Table 121 and Table 122. Figure 134 illustrates the low individual and herd prevalence of brucellosis compared to other infections investigated within the context of the KGR.

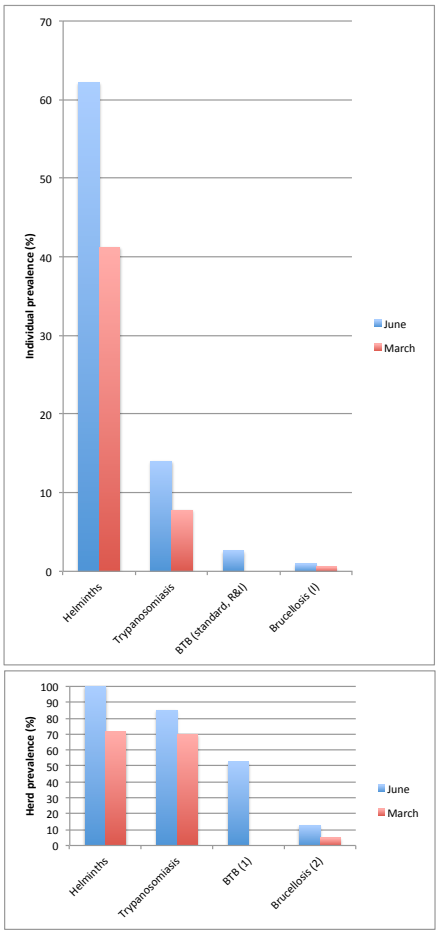


Figure 134 Individual and herd helminth/protozoal infection, trypansomiasis, BTB and brucellosis prevalence for June and March, 2011 (1- standard interpretation: reactors and inconclusives; 2-'infected' interpretation criteria)

	June (beginning wet season)								*March (mid dry season)*							
Disease	N ind +ve	N ind	Ind Prev	95 % CI	N HH +ve	N HH	Herd Prev	95% CI	N ind +ve	N ind	Ind Prev	95% CI	N HH +ve	N HH	Herd Prev	95% CI
Helminthosis +/- protozoal disease[1]	**1232**	**1981**	**62.2**	**53.5-70.9**	**40**	**40**	**100.00**	**91.19-100.0**	**711**	**1724**	**41.2**	**33.7-48.8**	**45**	**63**	**71.43**	**58.65-82.11**
Trematodes																
Paramphistomum cervi	850	1981	42.9	34.3-51.5	39	40	97.50	86.84-99.94	434	1724	25.2	19.9-30.5	45	63	71.43	58.65-82.11
Fasciola gigantica	106	1980	5.4	2.3-8.4	25	40	62.50	45.80-77.27	36	1724	2.1	1.3-2.8	22	63	34.92	23.34-47.97
Schistosoma bovis	3	1978	0.2	0.0-0.4	2	40	5.00	0.61-16.92	0	1724	0.0	0	0	63	0.00	0.00-5.69
Protozoa																
Eimeria bovis	352	1981	17.8	13.2-22.3	36	40	90.00	76.34-97.21	44	1724	2.6	1.3-3.8	21	63	33.33	21.95-46.34
Nematodes																
Oesophagostomum radiatum	296	1981	14.9	10.1-19.8	32	40	80.00	64.35-90.95	211	1724	12.2	7.4-17.0	30	63	47.62	34.88-60.59
Trichuris globulosa	237	1981	12.0	4.5-19.5	17	40	42.50	27.04-59.11	185	1724	10.7	7.9-13.6	39	63	61.90	48.80-73.85
Bunostomum phlebotomum	145	1981	7.3	3.7-11.0	19	40	47.50	31.51-63.87	124	1724	7.2	3.7-10.7	23	63	36.51	24.73-49.60
Cooperia pectinata	53	1981	2.7	0.5-4.9	10	40	25.00	12.69-41.20	86	1724	5.0	2.7-7.2	23	63	36.51	24.73-49.60
Strongyloides papillosus	12	1981	0.6	0.0-1.4	5	40	12.50	4.19-26.80	73	1724	4.2	2.5-5.9	27	63	42.86	30.46-55.95
Toxocara vitulorum	4	1981	0.2	0.0-0.5	4	40	10.00	2.79-23.66	0	1724	0.0	0	0	63	0.00	0.00-5.69
Ascaris vitulorum	0	1981	0.0	1.0	0	40	0.00	0.00-8.82	6	1724	0.3	0.1-0.6	6	63	9.52	3.58-19.59
Syngamus Laryngeus	0	1981	0.0	2.0	0	40	0.00	0.00-8.83	1	1724	0.1	0.0-0.2	1	63	1.59	0.04-8.53
Cestodes																
Moniezia benedeni	1	1981	0.1	0.0-0.2	1	40	2.50	0.06-13.16	8	1724	0.5	0.1-0.8	6	63	9.52	3.58-19.59

Table 119 Helminth/protozoal prevalence for June and March survey

([1] overall prevalence for cattle with one or more helminth/protozoal infection)

	June (beginning wet season)								*March (mid dry season)*							
Disease	N ind +ve	N ind	Ind Prev	95 % CI	N HH +ve	N HH	Herd Prev	95% CI	N ind +ve	N ind	Ind Prev	95 % CI	N HH +ve	N HH	Herd Prev	95% CI
Trypanosomiasis[1]	**278**	**1982**	**14.0**	**9.8-18.2**	**34**	**40**	**85.0**	**70.16-94.29**	**133**	**1709**	**7.8**	**6.6-9.2**	**44**	**63**	**69.8**	**56.98-80.77**
T. vivax	264	1982	13.3		34	40	85.0	70.16-94.29	115	1709	6.7		44	63	69.8	56.98-80.77
T. brucei s.l.	9	1982	0.5		7	40	17.5	7.34-32.78	12	1709	0.7		6	63	9.5	3.58-19.59
T. congolense	7	1982	0.4		4	40	10.0	2.79-23.66	7	1709	0.4		6	63	9.5	3.58-19.59

Table 120 Trypanosome prevalence for June and March survey

(Source (Santirso-Margaretto et al., 2014) ;[1] overall prevalence, cattle with one or more trypanosome species)

	June (beginning wet season)							
BTB	N ind +ve	N ind	Ind Prev	95 % CI	N HH +ve	N HH	Herd Prev	95% CI
Standard interpretation								
Reactor (R)	1	1945	0.1	0.0-0.2	1	40	2.5	0.06-13.16
Inconclusive (I)	50	1945	2.6	1.2-3.9	20	40	50	33.80-66.20
R&I	51	1945	2.6	1.3-4.0	21	40	52.5	36.13-68.49
Severe interpretation								
Reactor (R)	45	1945	2.3	1.2-3.4	21	40	52.5	36.13-68.49
Inconclusive (I)	27	1945	1.4	0.7-2.1	15	40	37.5	22.73-54.20
R&I	72	1945	3.7	2.1-5.3	26	40	65	48.32-79.37

Table 121 Bovine tuberculosis prevalence for June survey

Survey	*Brucellosis, interpretation criteria*	*N ind +ve*	*N ind*	*Ind Prev*	*95 % CI*	*N HH +ve*	*N HH*	*Herd Prev*	*95% CI*
June (wet season)	Infected herds	19	1972	1.0	0.0-1.9	5	40	12.5	4.19-26.80
	Infected & suspicious herds	25	1972	1.3	0.3-2.2	9	40	22.5	10.84-38.85
	Infected, suspicious & inconclusive herds	28	1972	1.4	0.5-2.4	12	40	30.0	16.56-46.53
March (dry season)	Field sRBT	10	1724	0.6	0.0-1.3	3	63	4.8	0.99-13.29

Table 122 Brucellosis prevalence for June and March survey using different interpretation criteria

11.3.1.3.1 Helminths/protozoa

11.3.1.3.1.1 Rumen fluke

Infection with *paramphistomum cervi* was the most prevalent helminthiasis for both dry and wet season (Figure 136). The immature flukes ex-cyst in the duodenum and jejunum causing severe parasitic disease that can be fatal. Once the adult flukes reach the rumen, the disease becomes relatively asymptomatic (MERCK, 2010).

11.3.1.3.1.2 Liver fluke

Liver fluke (*fasciola gigantica*) is the translation for 'hanta' given by veterinarians and animal health technicians working with Fulani and Hausa communities (confirmed by KIIs conducted with the Area Veterinary Officer and Project Officer).

A focus group discussion was held with KGR pastoralists, to determine ante and post-mortem signs associated with Hanta. Hanta was characterised by non-specific symptoms: rough hair coat, weight loss/ inappetance/ anorexia, ocular discharge, sneezing/ coughing/ panting, hard faeces and shivering. These symptoms could apply to acute liver fluke and numerous other disease conditions. When interviewed on the post mortem findings, the focus group participants all agreed that: "*There is an enlarged liver and when you cut it is watery, the liver is no longer wholesome, no longer firm, it becomes loose and fluidy, the colour of the meat of hanta carcases is darker, not the same as healthy animals; when you cut the liver sometimes you see the whitish worm*".

The liver pathology fits with acute fasciolisis but the reference to 'dark meat' is suggestive of black disease caused by *Clostridium noyi* in which bacteria proliferate in the liver after fluke migration. Black disease gets its name from the dark/black appearance under the skin due to rupture of capillaries in the subcutaneous tissue. Discussion of diagnostic and chemotherapeutic/prophylactic regimes for hanta with the AVO indicated that: "*For diagnosis we get faecal samples*" and that "*mild cases are treated with deworming boluses or drenches or injectables*" and that '*for prevention we use the hantavac vaccine*".

Hantavac is a *Clostridium novyi* vaccine for protection against Black disease.

The conclusion from the FGDs and KIIs, was that the disease commonly referred to as 'hanta' may have a dual aetiology incorporating not only acute liver fluke but also the liver fluke associated *Clostridium noyi* infection. Black disease is always fatal. Given a dual aetiology, prophylaxis should include both anthelmintic administration as well as vaccination with a clostridial vaccine. FGDs with livestock keepers also revealed that Hanta can mean liver, or general pathologies of the liver. When referring to liver fluke, some people use the term malewama-hanta to differentiate.

The prevalence of *Fasciola gigantica* was low at 5.4 and 2.1% for the wet and dry seasons respectively (Figure 136). The prevalence does not fit with the perception of hanta as the number one priority disease. There may be several reasons for the difference between perception of importance of disease and actual prevalence:

1. High case fatality rate of either acute *Fasciola gigantica* +/- *Clostridium novyi*- i.e. the majority of animals do not recover, unlike animals with trypanosomiasis or brucellosis, hence priority is based on the high mortality of this disease as opposed to high morbidity of other conditions;
2. Misinterpretation of other disease conditions for Hanta- i.e. the Fulani may have a tendency to over-interpret *Fasciola gigantica* +/- *Clostridium novyi* in their cattle as the symptoms are non-specific and easily confused with other disease conditions;
3. The similarity in microscopic appearance and size of *Paramphistomum cervi* eggs and *Fasciola gigantica* eggs leading to over diagnosis of the former and under diagnosis of the latter (Figure 135).

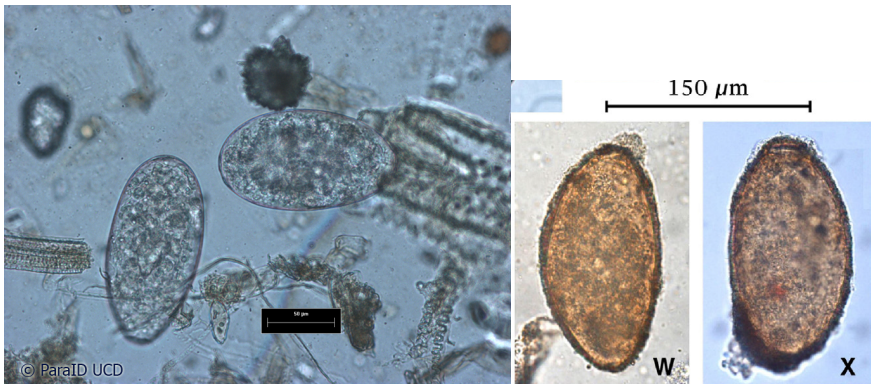


Figure 135 Microscopic appearance of *Paramphistomum cervi* eggs (left panel) and *Fasciola gigantica* eggs (right panel)
(Valero et al., 2009, UCD, 2008)

11.3.1.3.1.3 Schistosomiasis

Schistosoma bovis was found to have a low prevalence (Figure 136). This blood fluke occasionally causes parasitic gastroenteritis (PGE) through liver and small intestinal pathology but is most often asymptomatic.

11.3.1.3.1.4 Coccidiosis

Eimeria bovis infection (which causes PGE, predominantly in young calves) was found to be high during the wet season and lower during the dry season (Figure 136).

11.3.1.3.1.5 Gastrointestinal roundworms

Gastrointestinal roundworms (unlike the trematodes and protozoa), exhibited a similar prevalence in both wet and dry seasons (Figure 136). Their life cycle includes a stage in an intermediate snail host, which only survives during the wet season. Transmission during the dry season is either entirely interrupted or only occurs at specific wet areas able to sustain the snail.

The most prevalent GI nematodes (highest to lowest) were *Oesophagostomum radiatum*, *Trichuris globulosa, Bonostonum phlebotomum, Cooperia pectinata* and *Strongyloides papillosus* (Figure 136). Infection with these nematodes occurs from ingestion of contaminated pasture or water and may occur from infection through the skin as a result of contact with contaminated pasture. *Strongyloides papillosus* and *Bonostonum phlebotomum,* which infect cattle through the skin, can be associated with pneumonia and coughing since larvae migrate through the lungs (passing into the general circulation and then to the lung vasculature). Gastrointestinal roundworms cause varying degrees of parasitic gastroenteritis (PGE) including symptoms of diarrhoea , +/- anaemia, loss of appetite and reduced weight gain.

Disease severity depends on the age of the animal, previous exposure/immunity of parasitized host, type of infecting specie(s), and the overall worm/larval burden within the gastrointestinal tract (GIT). Young stock (especially un-weaned calves) are more vulnerable to PGE since they have had no previous exposure and have naïve immune systems. Fatalities can occur in young animals as a result of severe PGE but are infrequent (MERCK, 2010). Some nematodes shed eggs and remain in the soil for years, which may explain why the dry season infection rate is similar to

that of the wet season. Eggs of *Strongyloides papillosis* are reported not to resist cold or dryness and the higher dry than wet season prevalence appears paradoxical.

Immunosuppression experienced during the dry season as a result of under-nutrition may make cattle more vulnerable to PGE through a reduced capacity of the immune system to fight against infection and a corresponding increase in the worm burden of individual animals. There may have been more calves around in March 2011 as there is a calving season during the dry season. This discrepancy could also be due to the treatment and prophylactic regimes used, as prophylactic deworming is undertaken in the wet season but rarely in the dry season.

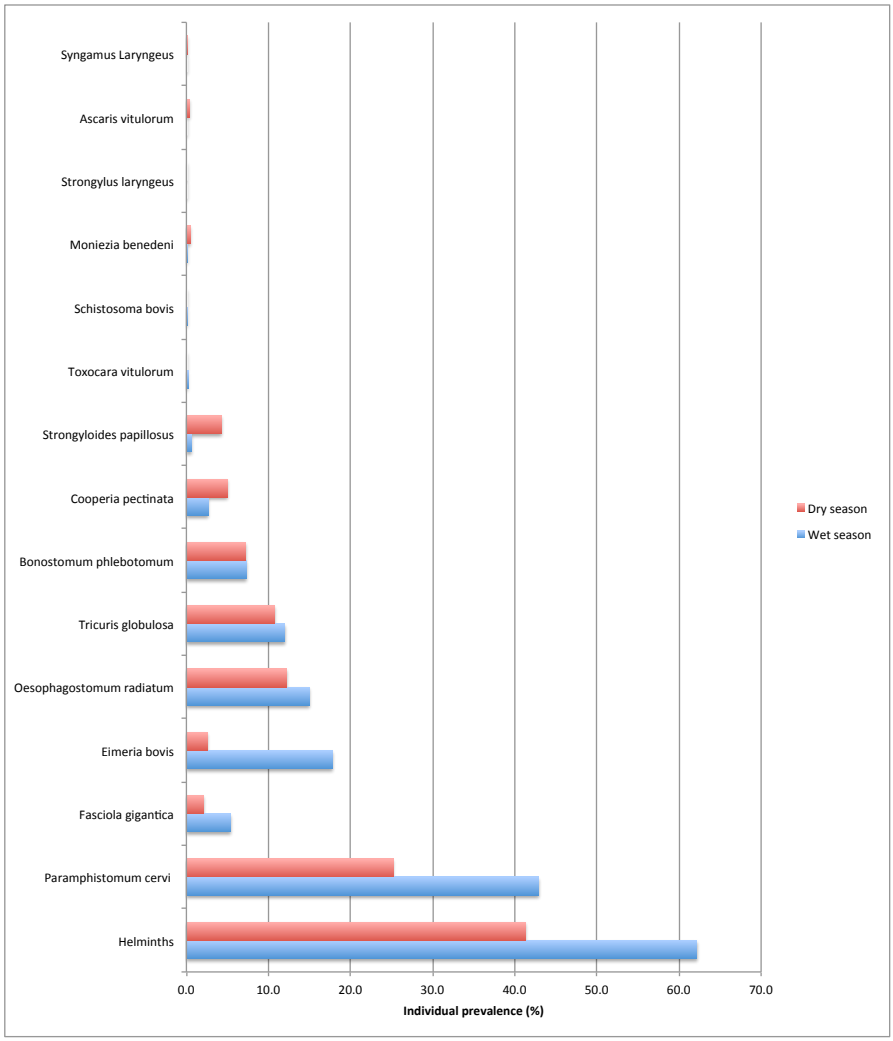


Figure 136 Individual prevalence of helminths/protozoa during dry season (March) and wet season (June)

11.3.1.3.1.6 Gastrointestinal tapeworms

The only cestode identified was *Moniezia benedemi*, which is non-pathogenic and an incidental finding in calves (Figure 136).

11.3.1.3.2 Trypanosomiasis

Trypanosomiasis is characterised by low livestock mortality but high morbidity. Individual prevalence of trypanosomiasis in cattle in KGR was moderately high, 14.0% and 7.8% during the wet and dry seasons respectively (Table 120). *T. vivax* was the dominant species observed. The results confirm the endemic character of cattle trypanosomiasis in the KGR. There was a high number of infected herds in KGR and within-herd prevalence was also high (Santirso-Margaretto et al., 2014).

11.3.1.3.3 Bovine tuberculosis

The KII with the AVO confirmed that there are not many complaints of BTB in the Kachia Local Government Area and that most respiratory disease is attributed to CBPP. BTB is seen in slaughterhouses but in his experience only rarely. During a FGD, one butcher described seeing 'caseous nodules' (which could potentially be tubercules) in the lungs at a rate of approximately 5 per month, but he did not have a name for this condition or know anything about its importance or relevance. CBPP was the commonly cited lung condition, described as enlargement of the lungs and consolidation of lung lobes (pneumonia), which was seen at rate of 1 per month.

Tuberculin skin testing to assess the prevalence of TB in cattle in KGR showed that even when using the most restrictive cut-off point (severe interpretation- see appendix) this would only yield 72/1945 (3.7%) reactors or inconclusives. However, 26/40 (65%) of herds were observed to have at least one reactor or inconclusive if the severe interpretation criteria were applied, which corresponds to a high herd-prevalence (Table 121). This would be expected where no control strategies (test and slaughter) are in place. The most likely scenario would be an underestimation of the true prevalence due to limitations in the sensitivity of the skin test. There may also be some breed issues. This scenario (low individual, low within-herd and high herd-prevalence) is similar to that described in pastoralist systems where cattle are not subjected to control strategies (Gumi et al., 2012) and similar to that for brucellosis.

Interpretation of these results without an insight into the true TB-status of herds (based on direct confirmation of disease) is difficult. Slaughter for collection of necropsy samples (retropharyngeal, mediastinal, thoracic and intestinal lymph nodes) for bacteriology confirmation of true infection status would have been optimal, but this was not feasible. Post-mortem information (detection of lesions of KGR animals) would be necessary to correctly interpret the data.

11.3.1.3.4 Brucellosis

The epidemiology of brucellosis in the KGR was described in detail in Chapter 8. Overall, individual prevalence was low and herd prevalence was higher (Table 122)

11.3.1.4 Approaches to disease control- cattle

Interviews in March and June 2011 showed that the majority of households (80-90%) spent most money on trypanocides, followed by antibiotics, dewormers, ectoparasiticides and finally vaccines in the previous year (Figure 137). The higher percentages reported in June 2011 may be related to differences in the way the question was framed between the March and June 2011. In March, the question was open-ended "*what have you spent on treatment and prophylaxis in the past year*". In June separate questions were asked for each category of drug, for example: "*what have you spent on trypanocides/ antibiotics/ dewormers/ pours-on/ vaccinations/ other drugs in your cattle between June 2010 and June 2011*", which would have prompted respondents to think about these drug categories individually.

The use of veterinary drugs by this community is widespread, with most drug categories being used by over 50% of households. Fulani use the drugs in five ways:
i) Treatment of the whole herd for prophylaxis;
ii) Treatment of individual sick animals;
iii) Combination of i) and ii);
iv) Treatment of a proportion of the herd for prophylaxis: a) Treatment of calves only for prophylaxis; b) Treatment of adults only for prophylaxis; c) Zoned treatment of 25 or 50% of the herd only.

The treatment regimen used depends on both drug type and season. Some households use block treatment to prevent disease whereas others treat cases with specific drugs

as and when they arise (Figure 138 Figure 139). More households use trypanocides and dewormers for whole herd treatment. Antibiotics are also used for whole herd treatment (a practice which may promote development of antimicrobial resistance). More households withhold chemoprophylaxis during the dry season and treatment tends to consist of treating individual sick animals. Some households only use dewormers in calves, and the use of ectoparasiticides is restricted to 25-50% herd by some. Figure 140 shows that more households undertake chemotherapy and chemoprophylaxis during the wet season.

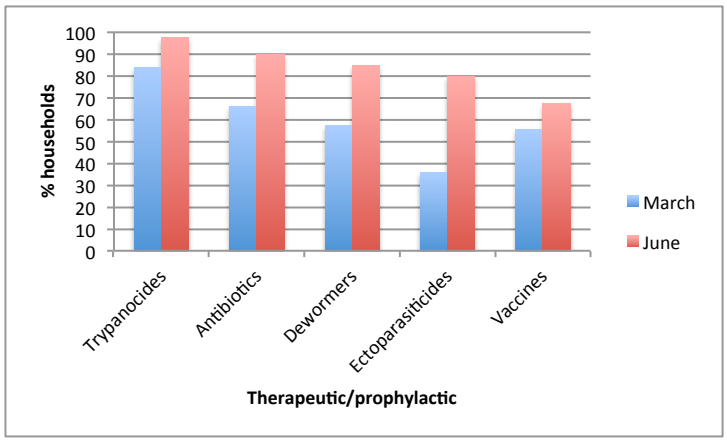


Figure 137 Percentage of households interviewed during March and June surveys that have used various therapeutics/prophylactics

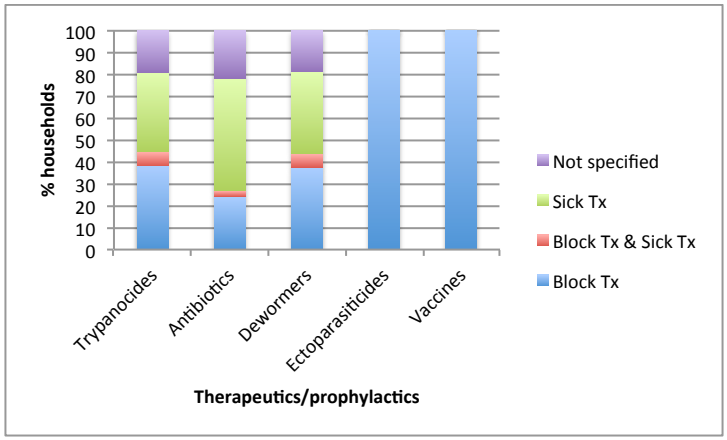


Figure 138 Percentage of households practising whole herd prophylaxis (Block Tx) or treatment of single sick animals (Sick Tx) or both, March survey

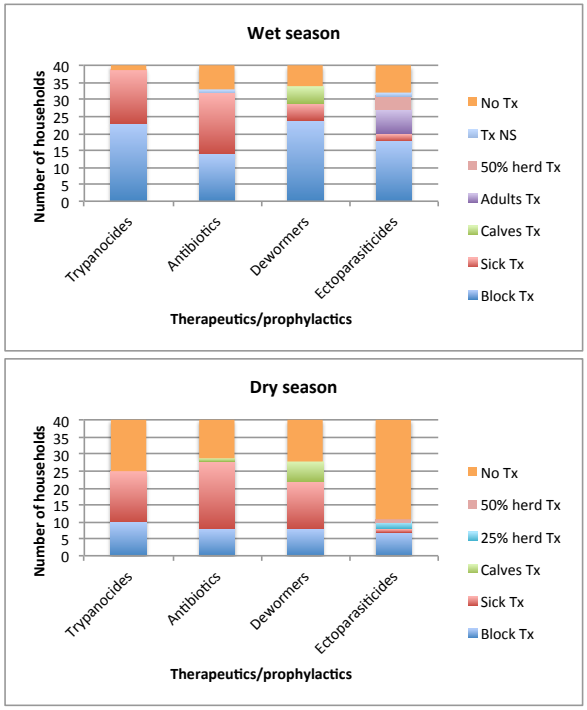


Figure 139 Number of households practising whole herd prophylaxis (Block Tx), treatment of single sick animals (Sick Tx), prophylaxis in calves only (Calves Tx) and prophylaxis in 25% or 50% of herd (25/50% herd Tx) or no treatment (No Tx) for wet season (top panel) and dry season (bottom panel), June survey

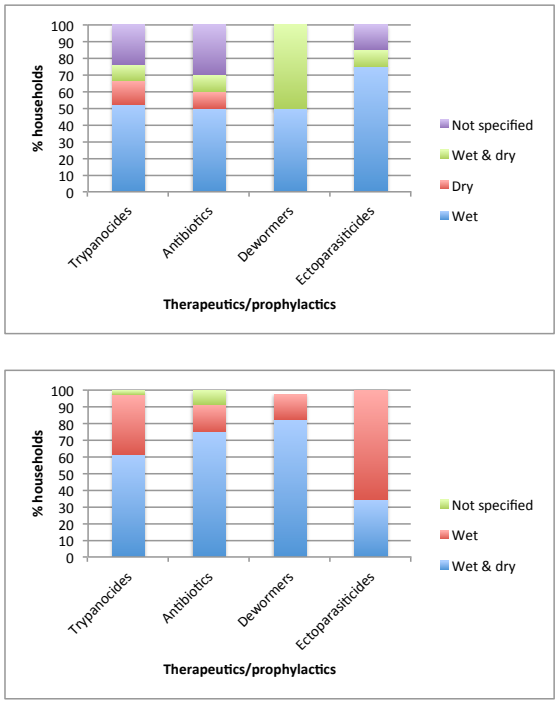


Figure 140 Seasonal use of different therapeutic/prophylactic drug types March (top panel) and June (bottom panel)

11.3.1.4.1 Trypanocides

Overall KGR households have a good understanding of how to use trypanocides for the curative treatment and prevention of samore (Figure 141). Survey data from June 2011 demonstrates better knowledge than that of March 2011, but is largely attributable to the improved structure of questions in the June questionnaire rather than a disparity in household knowledge. In June 2011 most households reported using the sanative pair (diminazene aceturate and isometamidium chloride) for treatment of all animals in the herd during the wet season. Isometamidium is both curative and prophylactic. Isometamidium would be expected to provide protection the treated animals for approximately three months (depending on the challenge). Diminazene is used for mass prophylaxis but it is more widely used for the treatment of sick animals - appropriate as the drug has curative and not prophylactic properties. Households reporting use of diminazene and isometamidium for treatment of sick animals, a practice more common during the dry season corresponds to households using either one drug or the other for the treatment of tyrpanosomiasis cases. High doses of isometamidium and diminazene are both curative. Isometamidium is used less frequently for treatment of trypanosomiasis since this drug is more expensive than diminazene, a finding confirmed through KIIs with vet drug traders in KGR.

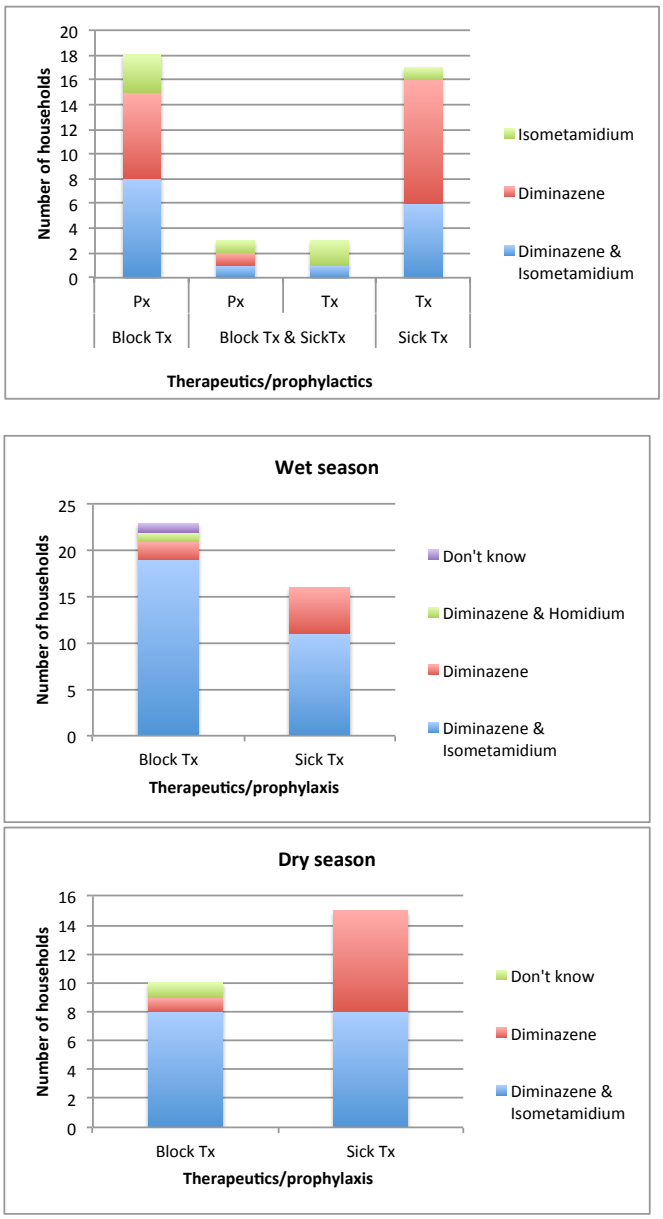


Figure 141 Number of households using different trypanocide regimes for whole herd prophylaxis (Block Tx, Px), treatment of sick animals only (Sick Tx, Tx) or both in March survey (top panel) and June survey (Middle panel- wet season; Bottom panel- dry season)

11.3.1.4.2 Antibiotics

The most commonly used antibiotic was referred to as 'LA', or long acting oxytetracycline or amoxicillin during (Figure 142 and Figure 143). The manner in which antibiotics are applied within the KGR community gives cause for concern.

Firstly, the knowledge of conditions that can be treated with antibiotics was poor; respondents mentioned using antibiotics to treat cases of hanta (liver fluke/clostridium) and samore (trypanosomiasis). Although antibiotics may be

indicated to treat secondary bacterial infections arising as a result of these two conditions, the use of antibiotics alone is not curative for these diseases.

Secondly, the indiscriminate use of antibiotics for whole herd mass treatments is poor practice and may promote development of antibiotic resistance.

Thirdly only a limited range of broad-spectrum antibiotics are used, which aids development of resistance (Figure 142 and Figure 143).

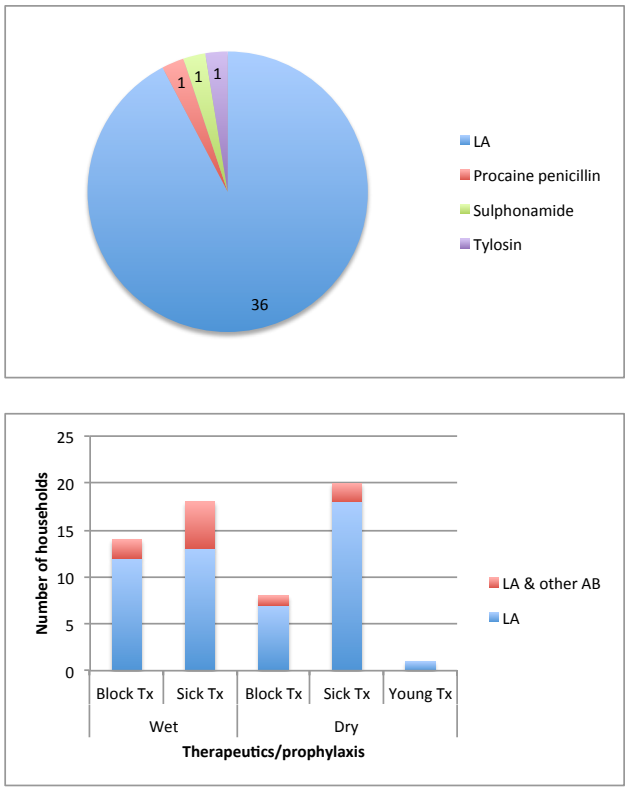


Figure 142 Number of households using specific types of antibiotic (top panel) used by March survey households and treatment/prophylaxis regime used (bottom panel)

It would appear that the Fulani apply a similar regime to that developed for trypanosomiasis – mass treatment at the beginning of the wet season – to antibiotic use. Many households reported simultaneous treatment of all their animals with antibiotics and trypanocides as part of their prophylactic regime. It is of concern that the Fulani do not respect the milk and meat withdrawal periods for any drug (essential for both trypanocides and antibiotics).

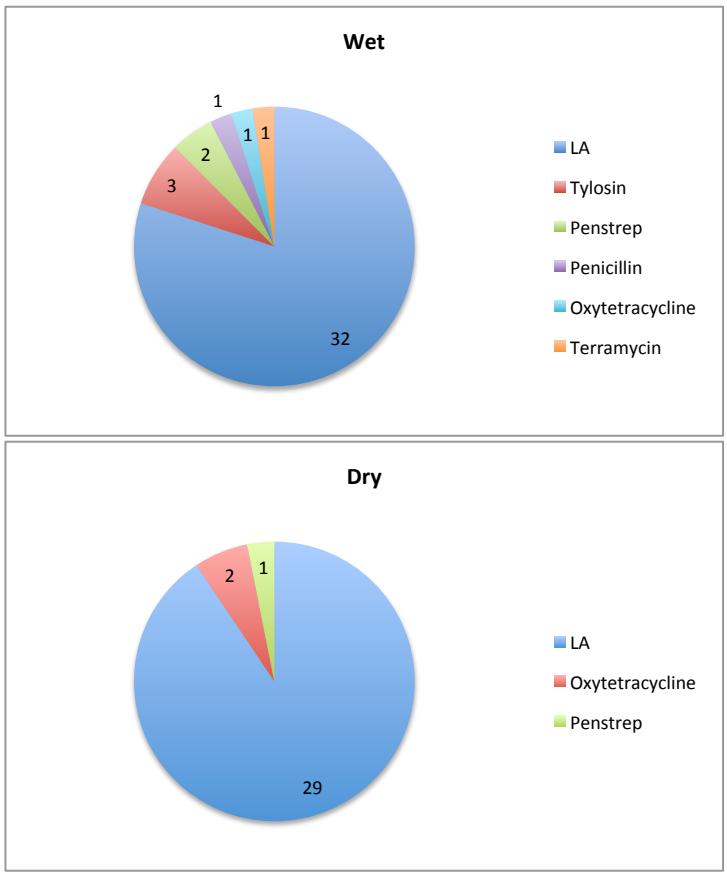


Figure 143 Number of households using specific types of antibiotic used during wet (top panel) and dry season (bottom panel) for June survey

11.3.1.4.3 Endoparasiticides

The most commonly used de-wormer was albendazole, followed by ivermectin and levamisole, either administered as oral suspensions, boluses or injectables (Figure 144 Figure 145). Most households use albendazole in combination with other anthelmintics (either levamisole or ivermectin or both), good practice to avoid development of resistance, and shows knowledge that levamisole and ivomec have no effect on flukes and must therefore be used in combination with albendazole to treat or prevent hanta (*Fasciola*) as well as goli (GI roundworms). A minority of households use ivermectin only, which has no flukicide effect. One household mentioned using 'magani goli', a traditional remedy for goli.

During the wet season prophylaxis is undertaken more often than treatment of individual sick animals, and the reverse is observed for the dry season. This fits with the higher wet season prevalence of GIT nematodes and flukes. The faecal worm

egg count (FWEC) values for the surveys were found to be 700 eggs per gram maximum, which is not high and indicates that worm burdens are kept low with the current deworming strategy. A large number of calves were found to be free of helminths, which fits with the practice described by one man during a FGD:

"*we believe in deworming the calves rather than the adults*".

PGE in adults is less severe and offers a good strategy to reduce the overall cost of deworming by preventing the disease in the age group most at risk of severe and potentially fatal parasitaemia.

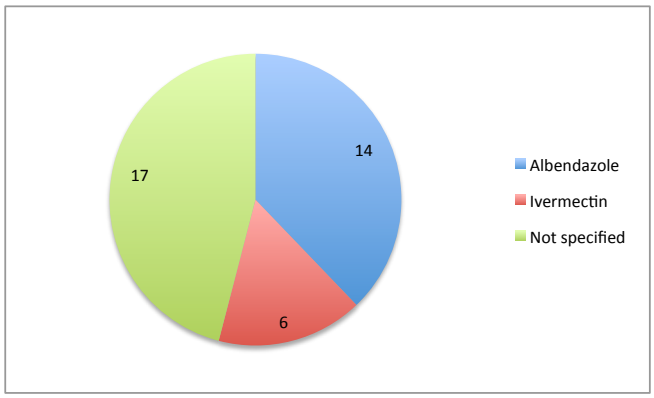


Figure 144 Number of households using specific types of dewormers, March 2011.

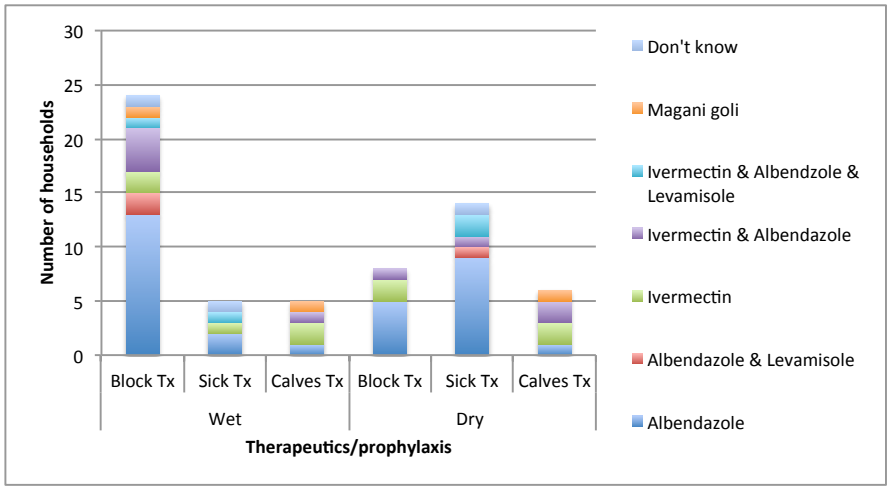


Figure 145 Number of households using specific deworming regimes, June survey

11.3.1.4.4 Ectoparasiticides

Most households reported using spray rather than pour-on ectoparasitic formulations. Reasons given for ectoparasitic use was predominantly to keep ticks away rather than

flies. Cypermethrin and deltamethrin were most commonly used, and whole herd block treatment during the wet season was the most widely practised regimen (logical as the wet season corresponds with peak tick and fly burdens) (Figure 146). Some households engage in zoned prophylactic use of ectoparasiticides to adult animals. Exposure of young animals to ticks promotes infestation and development of tick borne disease resistance through the phenomenon of endemic stability (Jonsson et al., 2012). Other households practice 'zoning' of ectoparasiticide in which only a certain percentage of the herd was treated, which may also be an adaptation to prevent perturbation of endemic stability.

Respondents reported the use of organophosphates and deltamethrins licensed for crop rather than animal use. Products were used to spray the area near the homestead and to treat a few cattle. Pesticides for crop application are more concentrated than those licenced products for animal use and raise concerns about toxicity to animals treated with these formulations. The driver for the use of crop products over animal-specific formulations is cost. Crop pesticides are cheaper and are commonly diluted for use in animals, a common practice which is likely to have adverse effects in cattle and which could impact on tick resistance.

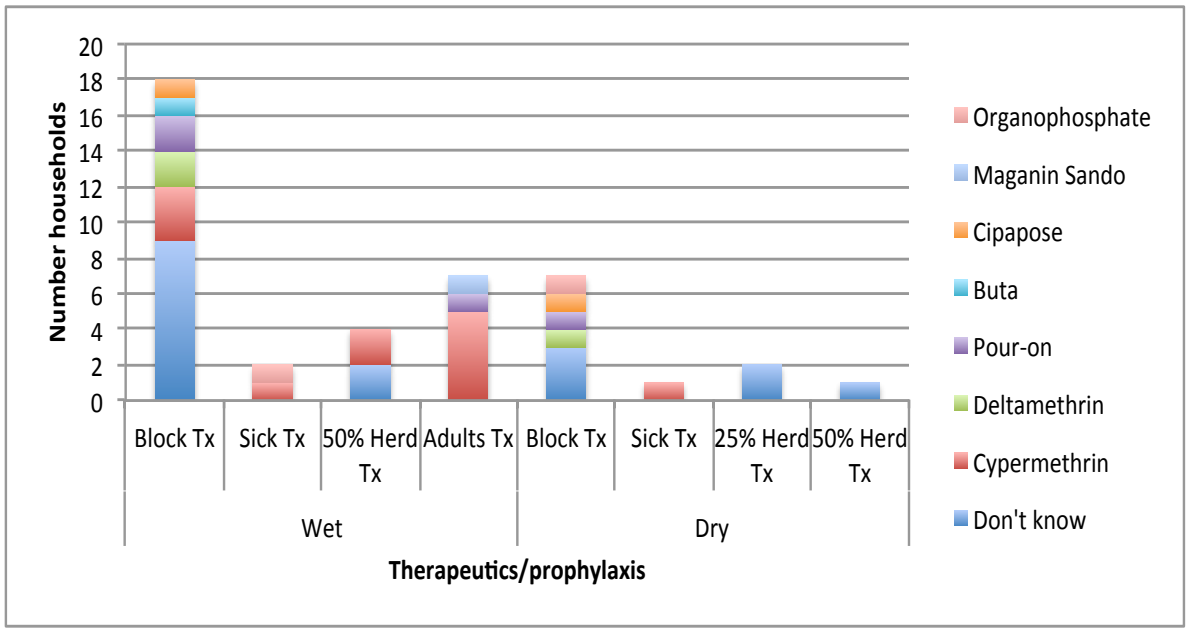


Figure 146 Number of households using specific therapeutic/prophylactic ectoparasitic regime, June survey

11.3.1.4.5 Vaccines

Not all households reported using vaccines, despite some respondents claiming that vaccination of their cattle was undertaken as part of a government programme. It is clear that these programmes fail to target the whole population and fail to achieve adequate vaccination coverage to achieve herd immunity and protection.

A KII with the Project Officer of the KGR revealed that the government have well-established vaccination campaigns in certain areas, e.g. Kaduna. The AVO from the Kachia government veterinary clinic confirmed that their clinic organises annual vaccination campaigns funded through local government subsidies (each farmer pays only 20N per dose) for intensive/commercial farms located within close proximity to Kachia town. The AVO estimated that 11,300 cattle had been vaccinated in the Kachia LGA with hantavac in the past year. The project officer of the KGR, claimed that officially the state government has a mandate to provide inhabitants of the KGR with subsidised vaccinations, but confirmed that had never been undertaken: "*They have never carried out a vaccination campaign here in the grazing reserve*".

The KGR community access vaccines in several ways:

(i) the 'informal' route by going to 'open markets' where counterfeit CBPP/hantavac and HSV vaccines are commonly sold.

(ii) Access through contacts working at the NVRI in Vom bringing vaccines in person to the KGR (Ducrotoy, M., personal observation). The KGR community confirm the number of doses required, and NVRI will send a staff member to deliver these. There are two problems related to this informal system. Firstly NVRI cannot always provide the total number of vaccines requested due to constraints regarding vaccine production and limited availability of doses, and secondly once the vaccines are delivered to the KGR community, the cold chain is not maintained. Community members describe vaccination as a 'disappointment' claiming that: "*They have to wait so long for the vaccine that by the time I vaccinate the animal it is already infected and even with the vaccine the animal becomes worse"*.

Finally (iii) households sometimes take advantage of government vaccination interventions being undertaken in an area to which they migrate during dry or wet

season transhumance. Households migrating to the Jos Plateau, for example, can take advantage of vaccination campaigns organised by NVRI Vom, which is within close proximity of Jos. The KGR community are willing to spend money on vaccines, and vaccine availability rather than demand is the limiting factor.

NVRI produce twelve different vaccines for ruminants including bacterial vaccines - CBPPV (contagious bovine pleuropneumonia), brucella S19 (production of this vaccine is on hold), haemorrhagic septicaemia (pasteurellosis), hantavac (for *Clostridium novyi*) and viral vaccines - peste des petits ruminants (PPR). The range of vaccines available is reflected in the answers given about types of vaccines used during the March and June surveys (Figure 147). CBPP and Hantavac (*Clostridum novyi*) were described as the most widely used vaccines. Some respondents reported using rinderpest vaccine; it is possible this was used instead of PPR vaccine or they may have been sold old TCRV stock as part of the informal black market drug trade.

No KGR household reported using the *brucella* S19 vaccine, highlighting a mismatch between local demand for a control tool for *Brucella* and its actual availability. However, since the S19 vaccine needs a veterinarian to administer, this clearly limits its application in any context where communities have no access to primary veterinary services. The wide use of the hantavac and CBPPV demonstrates that when demand and availability/ supply is matched, good vaccination coverage can be achieved. Community acceptance of vaccines is widespread and other vaccines could easily be introduced into KGR if they were affordable and for diseases considered to be important by the community.

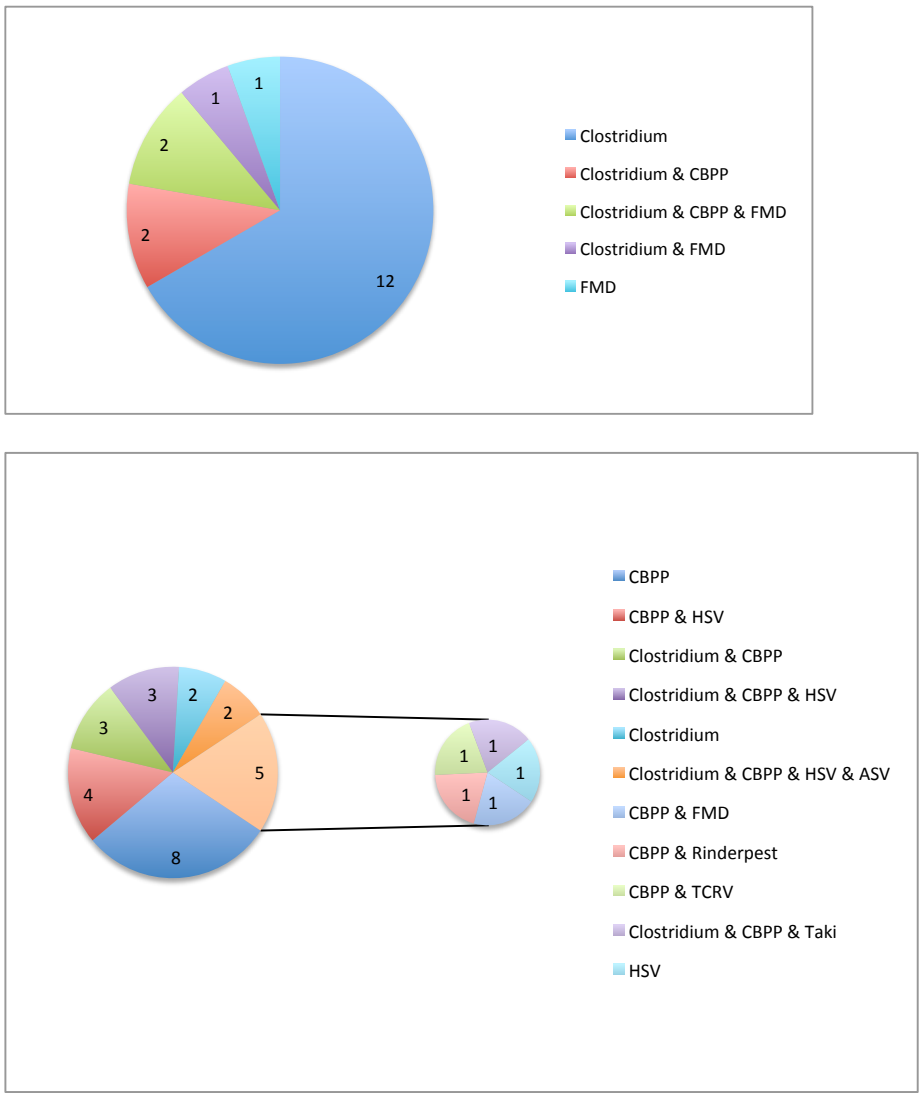


Figure 147 Number of households using specific vaccination regimes for March (top panel) and June (bottom panel) surveys

(CBPP- contagious bovine pneumonia, FMD- foot and mouth disease, HSV- haemorrhagic septicaemia, ASV- anthrax spore vaccine, TCRV- tissue culture rinderpest vaccine)

11.3.1.4.6 Other drugs or animal health expenses

To capture information on use of traditional remedies in cattle, households were asked if they spent money on drugs other than trypanocides/ antibiotics/ dewormers/ ectoparaciticides/ vaccines and to describe any other health expenses for cattle in the last year. Respondents mostly described using multivitamins in injectable form and 'kanwa' (mineral licks) for pica, a common complaint, and concentrate feed to supplement feeding during the dry season.

11.3.1.4.7 Perceived availability and suitability of veterinary services

Pastoralists were asked where they obtained animal health advice if their animals became sick: "*The moment we observe the animal is unwell, we observe symptoms, if it is a disease we already know we will get drugs we know and administer the drugs ourselves; then if it is an unknown disease we report to a vet or paravet and he will advise on drugs to administer*".

They were asked how long it took to get hold of that person, how far away they were and how much this service cost: "*sometimes going to the vet clinic or project office is a bit difficult due to the cost of going there and when you get there the vet or paravet may not come to have a look at your animals immediately; you need to take a motorcycle taxi there and back (800N) to go to the state vet clinic in Kachia (although some people go as far as Zonkwa to see the vet there, which is even more expensive) and if the vet is not available when you get there you need to make an appointment, which may take a long time; with drugs, the call-out fee and the consultation you can pay up to 50,000 N for treatment of your animals; because of that cost and the delay we prefer to use and buy drugs here as they are only 400-500 N and you administer the drug yourself, and this costs you 100 times less*."

When asked about the cost and quality of the veterinary services available in KGR: "*It is a bit expensive but we do not mind paying providing the service is readily available and effective. It is not the money we mind, but the timing. We have money and are willing to pay for the service but good drugs and vets are not within reach*."

When asked about their vision of how veterinary services in the KGR could be improved they answered: "*The major thing we would like is to have is a vet clinic at the centre of the reserve. The clinic should have an ample supply of drugs so we would have good drugs readily available*."

Responses emphasise that veterinary advice is rarely sought for treatment or prophylaxis. KGR community members draw upon their indigenous knowledge to diagnose conditions, and then buy and administer the drugs themselves. The KGR community live in a primary veterinary service vacuum and must rely on their own knowledge and expertise to deal with animal health problems in their animals.

11.3.1.4.8 Practices related to purchasing of drugs

During FGDs with men (pastoralists) enquiries into the origin of drugs purchased were made: "*We buy from the veterinary clinic at the local government capital (Kachia), from Vom (NVRI), from the market in the reserve, the market in the town closest to Ladduga (Crossing) or the market at Marere (cattle market) and also from Kachia Market*".

When asked if they asked for clinical advice from the drug sellers they answered: "*You tell the drug seller the symptoms observed and then he will give you drugs that are appropriate based on the list of symptoms you give him*".

In most cases, the drug sellers are traders or paravets with limited clinical knowledge, which raises concerns about the quality of advice provided.

11.3.1.4.9 Number of cattle treated and number of treatments

During the survey undertaken in June 2011 respondents were asked, for each drug type, the number of cattle treated over a one-year period and the number of treatments given to each animal. Figure 148 confirms the previously observed trend whereby trypanocides and dewormers are used for whole cattle herd mass treatment during the wet season. The mean percentage livestock vaccinated per household is 66%, which may reflect limited availability, since most respondents were aware that vaccines should be administered to the whole herd. The mean percentage treatment across all drug categories during the dry season is lower because households tend to treat sick animals rather than engage in whole herd prophylaxis.

The average number of treatments administered during the wet season for trypanocides was two, which aligns with a strategy whereby prophylaxis is undertaken at 3 monthly intervals (the recommended regimen in situations of intermediate challenge). Deworming should be undertaken at the same frequency, but households only undertake one round of treatments during the wet season. This fits with an observation by the PO of the KGR that: "*The pastoralists should be enlightened on some aspects of disease control; they only deworm their animals once during the wet season or if there is a problem*".

Ectoparasitic treatment is undertaken at short intervals during the wet season, with most households spraying their animals every one to two weeks due to the high tick (and to a lesser extent fly) challenge. On average, antibiotics are only administered once during the wet and once during the dry season, because the community uses long-acting antibiotic preparations that only require one administration.

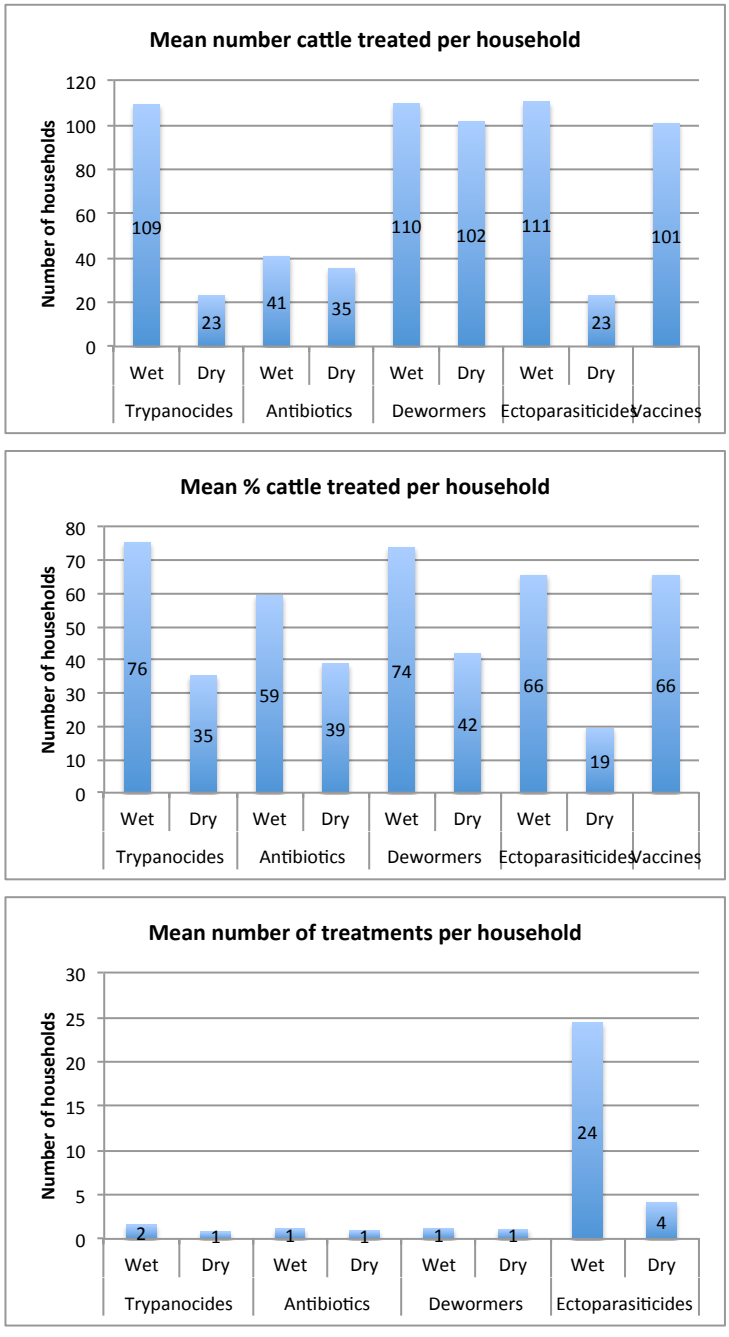


Figure 148 Mean number of cattle treated (top panel); Mean percentage of household cattle treated (middle panel) and mean number of treatments given to a single animal over a one year period, June survey

11.3.1.5 Household expenditure on cattle health

Seasonal household expenditure, treatment of all animals for all treatments indicates that wet season trypanocide treatment surpasses that of all drugs (Figure 149).

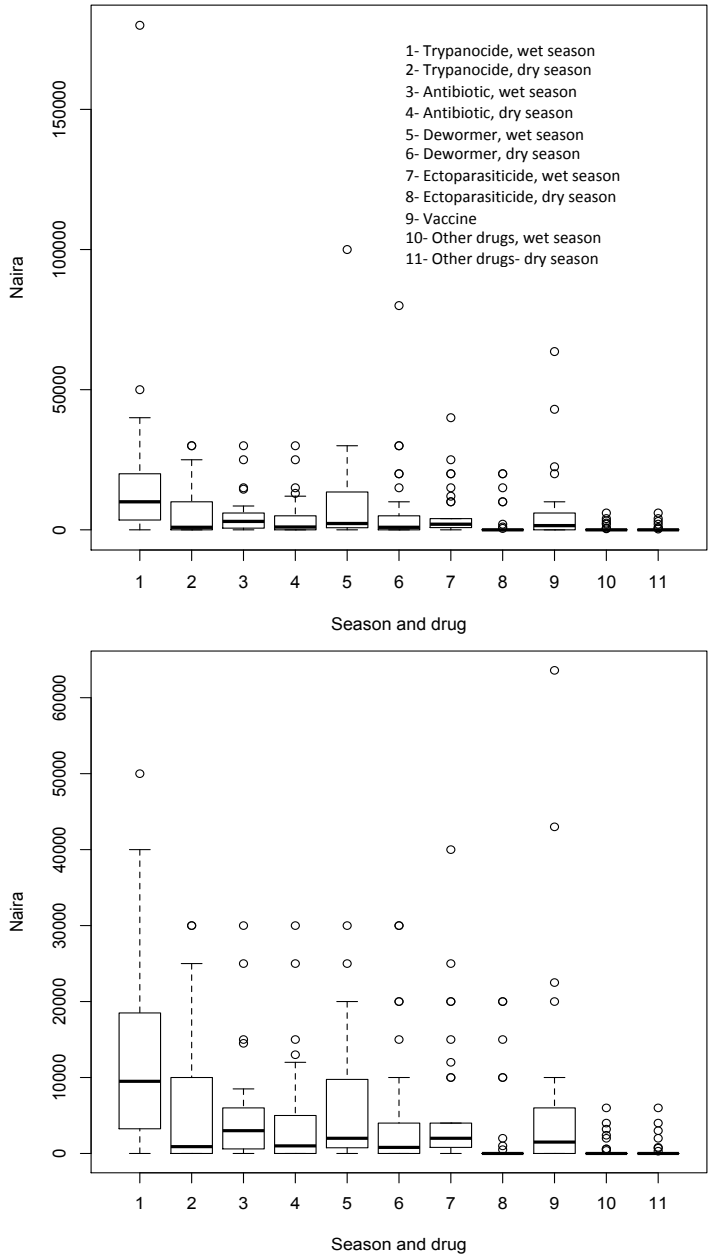


Figure 149 Household expenditure on animal health by drug and season in Nigerian Naira including outliers (top panel) and excluding outliers (bottom panel), June survey

The mean seasonal household expenditure on drugs and associated vet fees (Figure 150) indicates that veterinarians are rarely called out. Vet fees are the highest associated with vaccination. Dewormers represent the second highest expenditure but trypanocide use during the wet season dominates expenditure.

When overall household expenditure of the 40 households sampled during June 2011 is examined (Figure 151), more is spent on trypanocides than on any other drugs. The sum spent during the wet season was 10,500 Naira (approx. 64 USD) and about a quarter of that is spent on other drugs.

Despite the community being willing to spend money on drugs for animal health, their annual animal health budget is too low to be appealing to the pharmaceutical industry and is one reasons why there is limited private investment in the development and marketing of new drugs for the Africa market. The disparity between the price of good quality veterinary drugs and the purchasing power of KGR community was illustrated by the setting up of a new drug store in the KGR centre. This store sold top quality veterinary drugs that were more expensive than the standard low quality, low price drugs routinely sold in the KGR (a bottle of oxtetracycline antibiotic for example, was 900 N from the new store as opposed to 200N for the same drug if bought from the traders on market day). When KGR community members were asked how they felt about the new shop, they said they knew the drugs were better but that they simply could not afford them. Drugs need to be the right price for the local market.

The average expenditure per animal and per dose for the different drugs and seasons is shown in Figure 152. The cost per dose for trypanocides is approximately 100 N or 60 cents (USD), slightly lower than the price for antibiotics and dewormers, which are all sold at a similar price per dose (45 cents). Ectoparasiticides are 10 N per dose, approximately 6 US cents. Vaccine prices are subsidised by the government, and cost between 20-40 Naira per dose (approximately 5-10 US cents).

The range (interquartile) in amount of money spent on drugs is high (Figure 152), especially for trypanocides bought during the dry season and for antibiotics, due to the community buying both genuine drugs and counterfeit drugs (which are much cheaper). A KII with a small drug shop selling genuine veterinary drugs (established

by a University of Edinburgh animal health project focusing on trypanosomiasis) sold genuine good quality drugs at a much higher price than the average amount actually spent by the KGR community across the different categories of drugs. The use of cheaper counterfeit drugs is widesread and is a major issue for the KGR community.

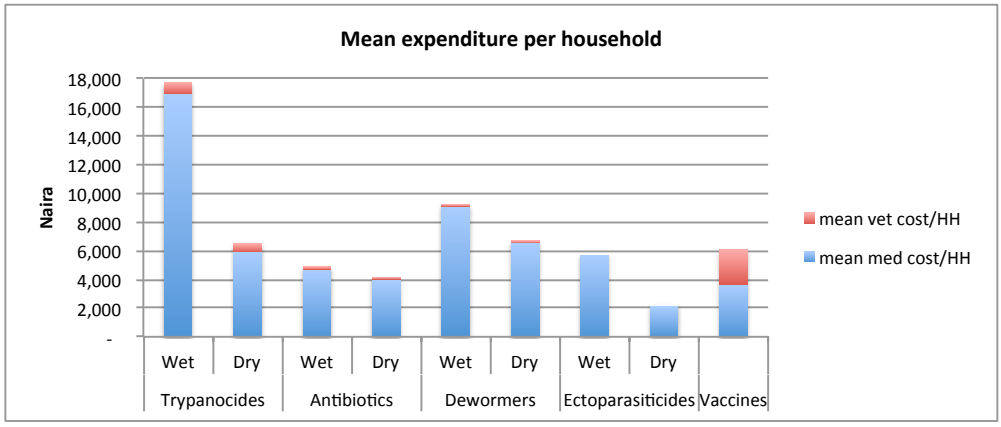


Figure 150 Mean household expenditure on medicine (med) and veterinary consultation (vet) costs by drug and season, June survey

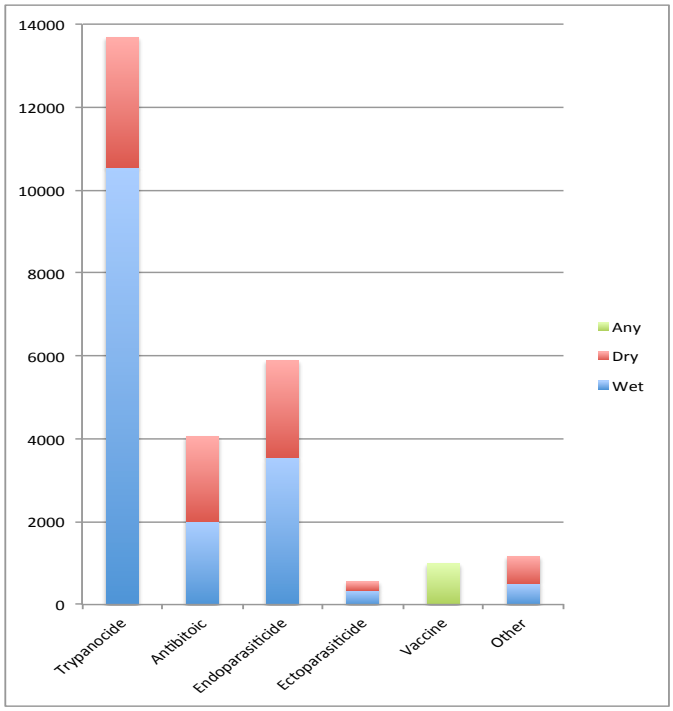


Figure 151 Total expenditure (Naira) across all households sampled by drug and season, June 2011

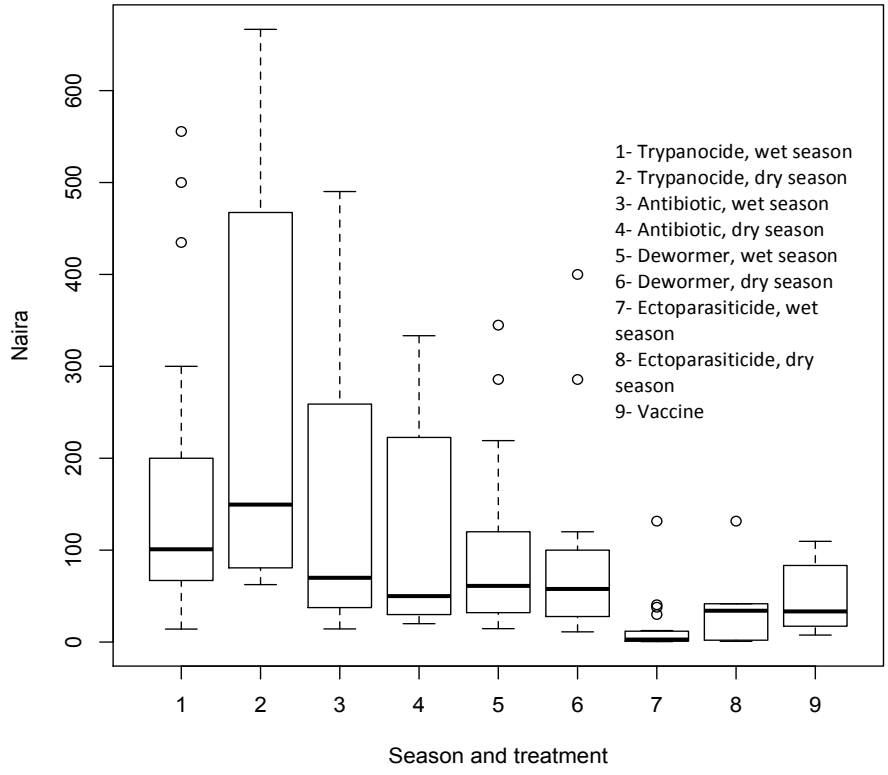


Figure 152 Average expenditure in Nigerian Naira per individual animal and dose for different drugs and seasons, June survey

11.3.1.6 Therapeutic and prophylactic approaches to small ruminant health

Small ruminant health is considered a lesser priority than cattle health in KGR, a reflection of the inferior monetary value of this species. Treatment priorities align with the disease priorities, the number one issue in small ruminants being 'hanta' (*Fasciola*) (Figure 153). Dewormers are more frequently used for the treatment of sick animals than for prophylactic whole flock treatment. Antibiotics were used for whole flock treatment (Figure 154), prompted by the high mortality in small ruminants reported in the March 2011 survey (suspected to have been caused by a PPR outbreak). The Fulani, mostly attributed this outbreak to hanta, samore and dumaral. Antibiotic treatment for PPR (although having no direct impact on the virus) can reduce mortality caused by secondary bacterial infections.

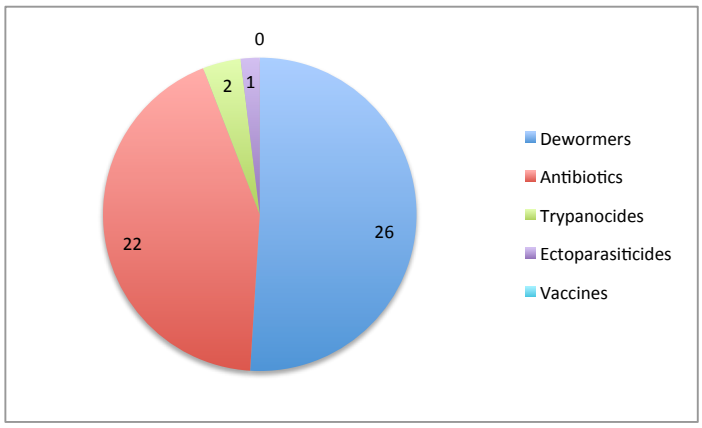


Figure 153 Number of households administering specific drugs to small ruminants, March survey

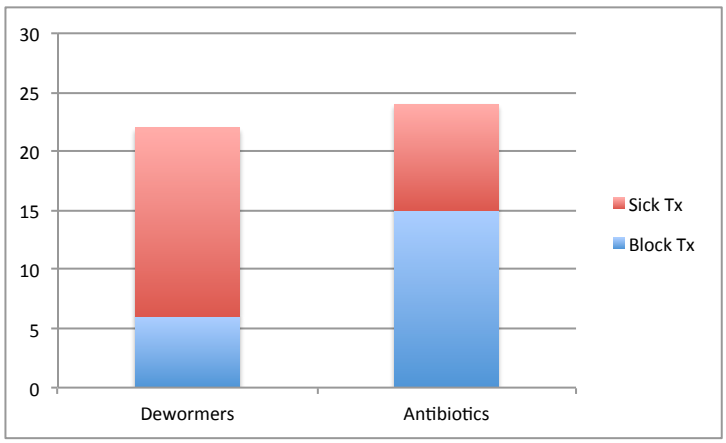


Figure 154 Number of households using specific dewormers in small ruminants, March survey

11.3.2 Human health and fevers

11.3.2.1 Burden of fevers

From the survey undertaken in October 2011 it was clear that fevers were a major concern for the KGR community. Almost half the individuals, 514 of 1124 (45.7%) interviewed claimed to be suffering from recurrent fevers that did not respond to treatment. Individuals were interviewed while being screened for brucellosis.

The household questionnaire showed the same trend with 34 out of 80 (42.5%) households interviewed answering yes to having one or more household member suffering from recurrent fevers. The number of persons suffering from general fevers over the last 6 months at household level is represented in Figure 155. Most households reported 4 persons suffering from fevers over this period, which

corresponds to 11-20% of all household members. Only one household did not report experiencing any fevers over the last 6 months.

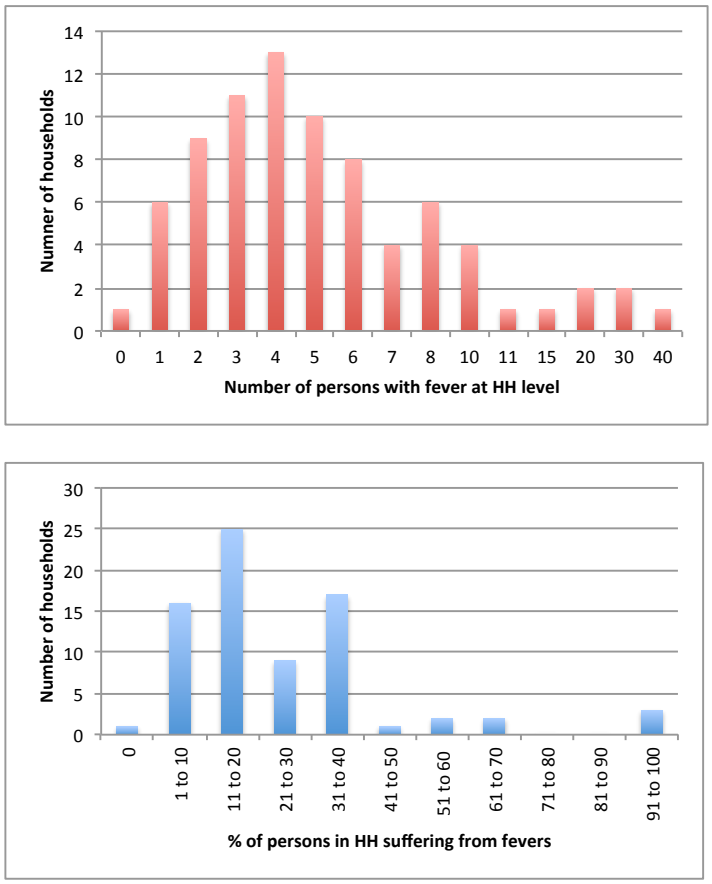


Figure 155 Persons in each household reported to have had fever in the last 6 months (top panel); Percentage number of persons suffering from fevers in whole household, October 2011 (bottom panel)

11.3.2.2 Household perceptions and practices related to fevers

Interviewees were asked i) what they thought were the main causes of fever (and to rank them in order of importance) ii) how people get the fever iii) how these different fevers are treated by the household iv) and what they perceived as the best treatment.

11.3.2.2.1 Perception of aetiology

Malaria was described as the number one cause of fevers (Figure 156), followed by typhoid, respiratory diseases, GI diseases, and yellow fever. GI diseases were often described as 'ulcers'. 'Ulcers' could also correspond to one of the symptoms of

typhoid. The respiratory diseases described could in part be caused by *Mycobacterium tuberculosis*, human tuberculosis.

The medical doctor (Dr Jamo) responsible for the KGR community, ranked the common diseases or conditions at his facility as 1 - Malaria; 2 - Typhoid; 3 - Gastroenteritis (vomiting and diarrhoea) and 4 - Respiratory infections. These were the same as the conditions mentioned by the KGR community. The community health technician of the Pathfinder clinic described the most common diseases observed as malaria, typhoid fever, pneumonia, measles, whooping cough and water borne diseases (vomiting and diarrhoea).

The medical doctor explained that he had only seen two true cases of 'fevers of unknown origin' (FUOs) in the last year. He referred one case to a referral hospital in Kaduna but the patient died, and the aetiology was never determined. He explained: "*A lot of people go to the quacks and don't get treated properly so they develop resistance which is why so many people have recurrent malaria even though they allegedly seek medical treatment*".

The human health technician echoed this sentiment: "*a lot of people self-medicate with poor quality drugs. If I see a case of malaria or typhoid and treat the person here in the clinic they will get better. In one day I get 20-30 cases of malaria and 90% of them will have taken drugs at home. People are very poor so will spend 5-10 N on cheap drugs before coming to the clinic*."

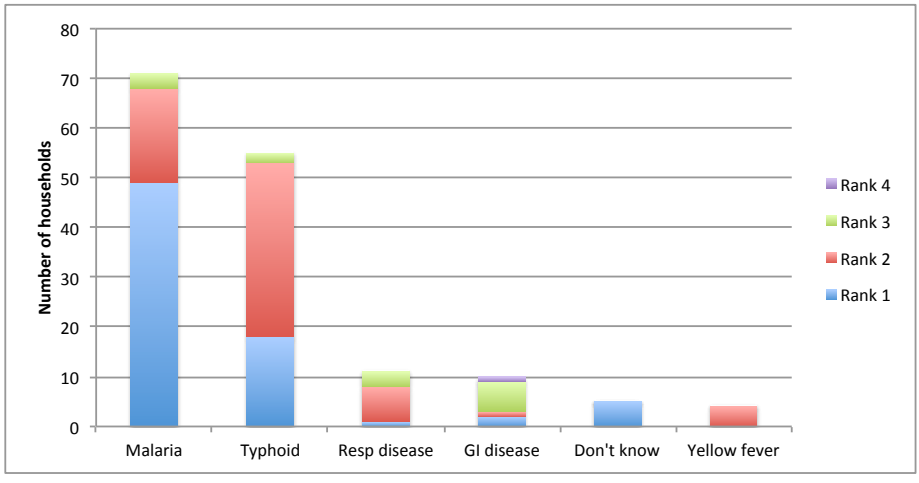


Figure 156 Aetiology and rank given for fevers experienced in the KGR, October survey

11.3.2.2.2 Knowledge on transmission

Knowledge on how people contract malaria was better than for typhoid (Figure 157). 'Ulcers' were reported to be associated with eating spices and peppers. The cause of yellow fever was unknown, and respiratory disease was attributed to cold weather.

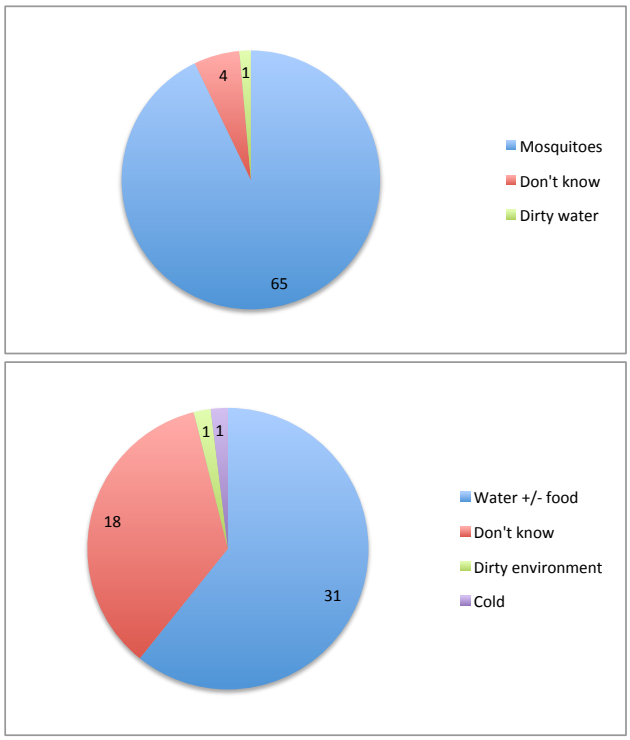


Figure 157 Answer given for mode of transmission of malaria (top panel) and typhoid (bottom panel), October 2011 survey

11.3.2.2.3 Treatment practices and perception of best treatment

Most people treated their fevers with cheap drugs bought from drug shops in the market centre of KGR or elsewhere (Figure 158). These drugs are often counterfeits and are sold for very low prices (10-20N). Many people reported using herbs for treatment. Since fake drugs do not work, people eventually attend clinics (Dr Jamo or Pathfinder) to receive treatment, reflected in the relatively high number of individuals that seek hospital care and western drugs. One person mentioned drinking raw milk as a cure for ulcers, which may be the basis for some individuals being reluctant to boil milk prior to consumption.

When people were asked which treatment they considered best for fevers, nearly all respondents were aware that western drugs and hospital treatment were better than

self-medication and herbs. This did not prevent them from trying cheaper treatments as a first line. Poverty, as eloquently put by the community health technician, is the main driver for this behaviour: "*People are forced to treat disease with the cheapest means possible as a first line and will only seek the more expensive treatment regimens if they do not get better*".

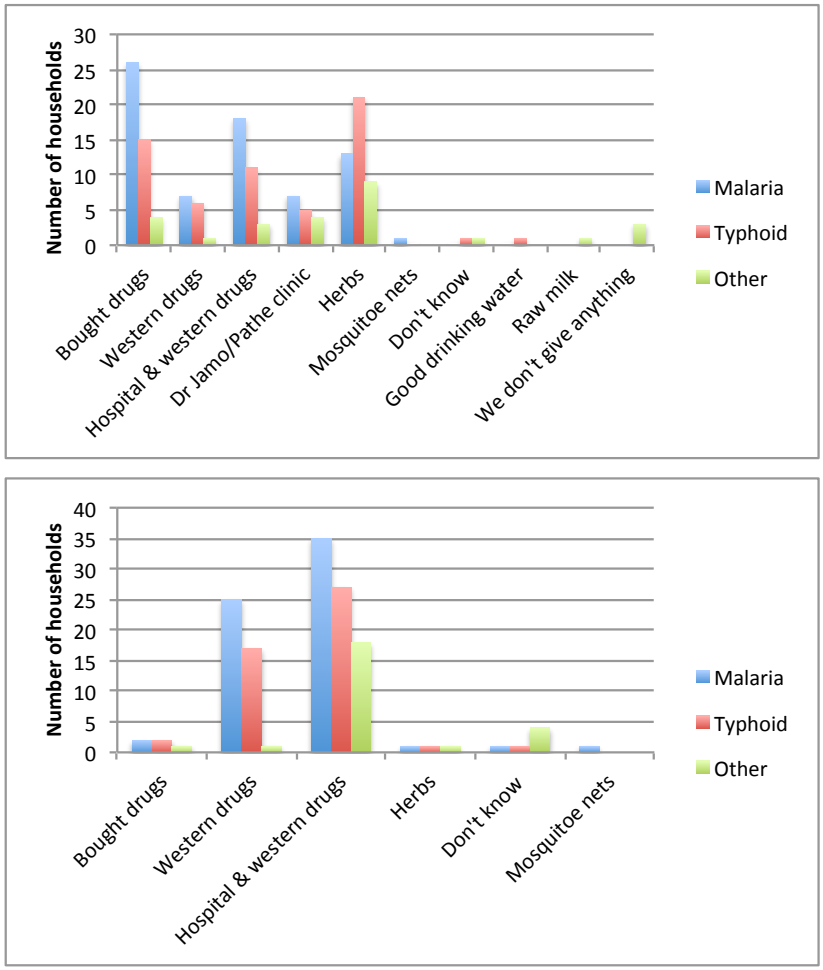


Figure 158 Drugs and/or treatment actually sought for fevers (top panel) and drugs and or treatment which respondent thinks is the best to treat fevers (bottom panel)

The percentage of households using different treatments for fevers in the 6 months prior to interview was summarised in Figure 159 (top) and is similar to that used to treat recurrent fevers (bottom). Between 81-93% visit the clinic run by Dr Jamo for treatment. Self-medication and herbs are the next most popular forms of treatment.

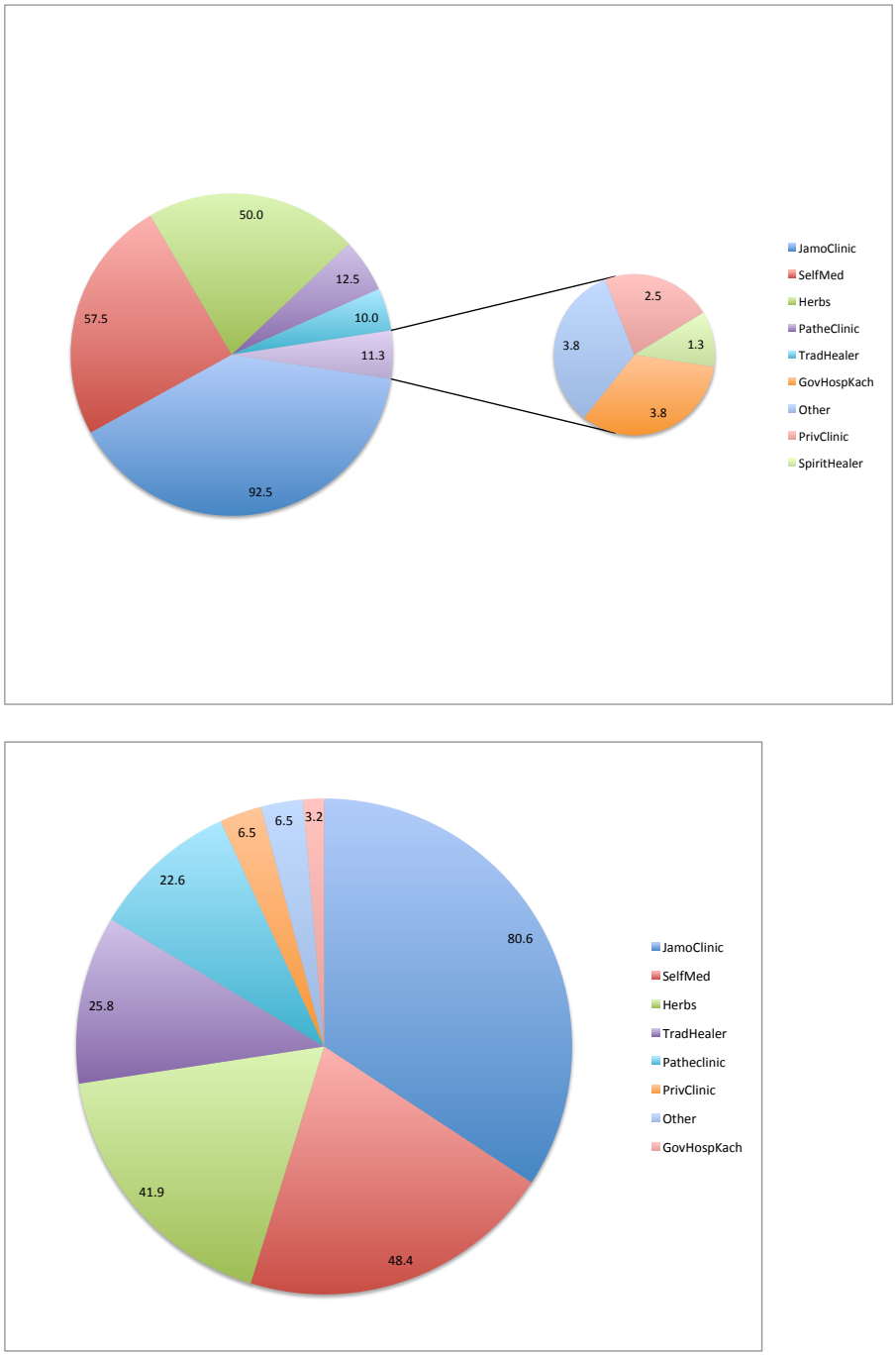


Figure 159 Percentage of households that have used the following facilities or modes of treatment to cure normal fevers (top panel) and to cure recurrent fevers (bottom panel)

11.3.2.2.4 Health seeking behaviour

To establish patterns of health seeking behaviour, FGDs were undertaken with groups of men and women. Both groups confirmed that most people use the health facilities within the KGR (the private clinic of Dr Jamo and the NGO funded

Pathfinder clinic) before leaving KGR to seek medical assistance. People will occasionally use a private clinic in Kachia or go to the state government hospital in Kachia. The men stated: "*In the past we used to go as far as Kachia but now with the big hospital of Dr Jamo and Ujena (Pathfinder clinic) we have felt serious relief and get good service from those two places. Dr Jamo having seen the problem will refer you to Kachia or Kaduna if necessary*".

FGD participants were asked about the popularity of traditional medicine: "*Before people used to use traditional medicine but less now. If conventional treatment does not work, then maybe we would try traditional medicine; though there are a few specialists of traditional medicine, modern orthodox hospitals have taken over the activities of traditional healers. It is not first line of action most of the time, except if Dr Jamo handles a case and believes such a case requires traditional medicines*."

The participants emphasised that often they would: *"Just treat themselves and buy tablets and syrups from chemists. There is a small chemist at Dr Jamo's, the Pathfinder clinic has a chemist and we also have chemists in the market and we also buy from outside drug sellers around during market day or we can go to Kachia to buy meds from drug stores."*

When asked if the current health facilities meet the needs of the community: "*Even if we don't have money we will be treated at Dr Jamo's Clinic or the Pathfinder clinic so we are very happy. In the government hospitals they don't always have doctors, but here at Dr Jamo's we always get very good quality service. We really like the fact that credit is available at Dr Jamo's and Ujena's clinic: if you cannot afford to pay today, you can pay later*."

11.4 Discussion

11.4.1 Animal health

Pastoralist knowledge and understanding of disease conditions and how to treat them is extensive in the KGR. Indigenous animal health knowledge in pastoralist communities has been transmitted from generation to generation. The lack of veterinary service in these communities forces pastoralists to depend on their intuition, knowledge, expertise and experience to deal with animal diseases. Mariner

(2002): "*Indigenous veterinary knowledge is based on oral tradition, shared information and the life experience of the individual*".

11.4.1.1 Animal health priority diseases in the KGR.

Data on indigenous veterinary knowledge as epidemiological intelligence can be combined with the results of formal epidemiological surveys to come up with a shortlist of priority diseases for cattle in terms of burden. The 'magnitude' of the disease burden was formally assessed through a combination of the following indicators, explained here below, to give an overall priority score [Priority score = A + (B x C) + D + E + F]. The lower the score the higher the priority (Table 123).

A. Community ranking (priority rank given by KGR respondents in questionnaires);
B. Prevalence ranking (rank of prevalence based on June 2011 survey or estimated from community intelligence if no survey was undertaken for a specific disease);
C. Severity ranking (overall qualitative estimate of how severe the disease is in terms of case fatality rate and for disease conditions which are rarely fatal the impact on productivity through reduced weight gain, reduced fertility etc., as well as duration of disease (i.e. is animal infected for life or is it a transient infection?)- mostly based on personal/expert veterinary knowledge;
D. Control tool availability ranking (current availability and accessibility of tool required to prevent or treat disease in KGR community);
E. Expenditure ranking (household expenditure on category of drug required to treat or prevent disease);
F. Zoonotic ranking (zoonotic potential of disease condition and propensity for impact on human health).

Disease	*Com. rank*	*Prev (%)*	*Prev rank*	*Sev. rank*	*Prev x sev*	*Exp. (Naira)*	*Exp. rank*	*Con. Rank*	*Zoo. rank*	*SCORE*
Hanta (fluke/blacks disease)	1	5.4	3	1	3	5880 + 147= 6027	2	1	2	9
Samore (tryps)	2	14	2	3	6	13,761+557= 14,318	1	1	2	12
Goli (PGE)	6	>14.9	1	3	3	5880	3	1	3	16
Fufu (CBPP)	5	NA	3	1	3	589	4	2	3	17
Boru (FMD)	4	NA	3	2	6	25	6	3	2	21
Bakale (brucellosis)	3	1	5	2	10	4054 x 0.01= 40	5	4	1	23
Tari (BTB)	7	2.3	4	4	16	0	7	5	1	36

Table 123 Priority ranking of cattle diseases for the KGR according to various indicators

Using this ranking Hanta and Samore were the two priority diseases of KGR, followed by goli, fufu and boru. The neglected bacterial zoonoses, bakale (brucellosis) and tari (bovine TB) come last. The situation in KGR confirms that for animal disease the 'usual suspects' dominate in terms of perceived burden. The same applies for human disease, with malaria being attributed as the major cause of fevers, (reflecting community perception without diagnostic confirmation).

The limitation of this prioritisation method is that the shortlist of diseases only includes diseases mentioned by the KGR community or diseases for which epidemiological surveys were conducted. Conditions such as tick-borne diseases should also be in this shortlist but due to lack of data or awareness of this condition by the KGR community, this disease was not considered.

Hanta ranked as a number one priority since this was the perceived number one cattle health issue for the KGR community. Although prevalence of *Fasciola gigantica* did not rank that high (no data is available on *Clostridium novyi* prevalence), severity of disease was scored '1' because the peracute form of fascioliasis is severe, with high case fatality (*Clostridium novyi* cases are invariably fatal). Since this dual aetiology disease is easily preventable through deworming with flukicides and vaccination with hantavac, a practice widely undertaken by the community, this disease presented a high expenditure ranking (total spent on dewormers, since most households used the flukicide levamisole) and high control tool availability ranking (flukicides can be purchased from the KGR and hantavac is locally available). A zoonotic rank of 2 was given because *Fasciola gigantica* is a zoonosis, although the extent of the burden of this disease in humans in KGR is unknown.

Samore ranked second. In this case the community ranking was high (second), the prevalence ranking was high at 2 and for severity samore ranked moderate at 3 (trypanosomiasis case fatality is low but cattle experience reduced weight gain, abortions and trypanosomiasis has been recognised to have a high impact on productivity (Shaw et al., 2014). Household expenditure on trypanosomiasis (sum spent on trypanocides and ectoparasiticides) was the highest recorded and drugs are readily available in the KGR, these were both given a top ranking. A zoonotic

ranking of 2 was given (human infective subspecies of *Trypanosoma brucei* has not been determined in the KGR).

Gastrointestinal roundworms ranked third in KGR. These were given a low rank by the community but showed the highest prevalence. The severity of disease ranked low since FWEC showed relatively low parasitaemia with adult animals being relatively asymptomatic (although disease in calves can be fatal). Expenditure on dewormers ranked third, and availability of drugs ranked 1st since these drugs are readily available in the KGR. Zoonotic potential is low to nil ranking 3rd.

CBPP ranked forth. Since this disease was not given a high priority by the KGR community, and there is no data on prevalence available this was given an intermediate rank of 3 based on case reports of respiratory conditions. Severity of disease was given a ranking of 1 because case fatality is estimated to be around 23-50% (Fadiga et al., 2013). Expenditure on the CBPP vaccine was calculated by multiplying the percentage of households that vaccinated against CBPP with the overall amount spent on vaccines, this was ranked quite low. Availability of CBPP vaccine was ranked 2 since NVRI produce this vaccine locally and distribute it frequently within the KGR. The zoonotic potential of this disease is nil.

FMD was given a low rank by the KGR community and no data on prevalence were available. Prevalence was estimated to be moderate and severity of disease was given a ranking of 2 as the disease can cause high case fatality in young animals. The household expenditure was calculated as for CBPP, and due to the low availability of the vaccine was very low. The zoonotic potential of this condition exists but is low.

Brucellosis was the second to last disease condition to be prioritised, based on the very low prevalence of this disease in KGR and the fact a vaccine is not readily available (NVRI produce S19 but the vaccine is currently unavailable).

BTB was the lowest scoring disease condition due to a low prevalence, low ranking by the community, low severity of disease (despite being chronic animals can live to old age), and most importantly the lack of context-appropriate disease control or treatment measures. Test and slaughter control for BTB is not appropriate in pastoralist settings and would not be accepted by the KGR community.

11.4.1.2 What are people doing to tackle animal disease in KGR and how can this be improved?

General recommendations for animal health would include the purchasing of better quality veterinary drugs (which are more expensive). The establishment of an annual vaccination program with NVRI would serve to reduce the burden of diseases such as *Clostridium novyi,* CBPP and FMD. The necessity and practicability of undertaking a brucellosis vaccination campaign is discussed in Chapter 10.

The approach for control and treatment of trypanosomiasis in KGR appears adequate. However, whole herd administration of antibiotic for disease prophylaxis for hanta and samore should be discouraged and the community educated as to the dangers of such practice. Deworming was adequate but the frequency of anthelmintic administration should be increased to three-monthly during the wet season. All use of crop pesticides for animal use should be discouraged.

11.4.2 Human health

11.4.2.1 Are fevers a health concern for KGR community?

With nearly 50% of the KGR community reporting to suffer from recurrent fevers over a 6-month period, fevers are a huge burden to human health. Key informant interviews with the two health providers of the KGR confirmed that patients presenting with recurrent fevers constitute the bulk of their work.

11.4.2.2 What is causing fever and how much is it costing?

Malaria and typhoid are the top two aetiologies for fevers as perceived by the KGR community. The medical doctor and community health technician ranked malaria and typhoid as the top two conditions seen overall. When questioned about 'recurrent fevers', both human health practitioners provided a similar answer. The main issue was perceived to be that most people suffering from malaria self medicate with cheap and ineffective drugs or herbs as a first line treatment. The rationale for choosing this treatment first is that with so many people suffering from fevers, the cost of treating these fevers at household level is high. The cheapest treatment option is selected first to keep costs down. Only when the fever recurs will affected persons seek medical assistance from Dr Jamo or the Pathfinder clinic to obtain treatment with more

expensive western drugs. To put the household health cost difference between self-medication versus clinic/western drug treatment into context the annual cost of treating fever via different methods is calculated below.

Calculations are based on an average of 6 fevers per household over a six-month period (based on questionnaire data):

Cost of self medication for one year = 6 x 10 N for meds x 2 = 120 N /HH/yr

Cost of treatment at Dr Jamo's clinic for one year = 6 x 500 N for meds and consult x 2 = 6000 N /HH/yr

Cost of consultation, lab work and drugs at private clinic in Kachia for one year = 6 x 2400 N for meds, lab and consult x 2 = 28,800 N/HH/yr

Costs range from 70 cents per year for self-medication of sick persons in a household to 4 USD per year for treatment at Dr Jamo's clinic to 175 USD per year for treatment with the best drugs at a private clinic in Kachia (excluding transport costs). KGR community members very rarely go to Kachia for treatment, as the cost is prohibitive. If one estimates that for every 12 cases of fever experienced per year and per household, 6 will get better with self-medication (fever resolving spontaneously rather than cure by drugs) and 6 will go to Dr Jamo's, the annual cost of health seeking for fevers is 20 USD. Households willingly spend 20 USD a year on cattle trypanocidal treatment alone. The 20 USD/HH/yr figure is similar to the average malaria expenditure of $1.84 per household per month (22 USD/HH/yr) found by Onwujekwe et al. (2000) in five malaria holo-endemic Nigerian communities.

11.4.2.3 What are people doing to tackle human disease and how can this be improved for better results?

As households only have 20 USD to spend on treatment of fevers per household per year, the best prospect seems to be finding ways to reduce the number of fevers themselves. Few people were aware that bed nets could be used as way to reduce mosquito bites and prevent malaria. Sanitation and hygiene (i.e. washing of hands before food preparation) would serve to reduce the number of typhoid cases.

Community education on the importance of good quality 'western' drugs obtained from Dr Jamo's or the Pathfinder clinic rather than self-medicating/using herbs may also be indicated, but the prohibitive costs of healthcare require that quality medical

care be subsidised so as to be affordable for all cases of fever rather than the ones that do not recover after self-medication. The term 'further' subsidised is used because the KGR community healthcare is already partly subsidised in that the Pathfinder clinic is a non-profit organisation and only charges drugs to the patients at cost-prices, and Dr Jamo personally also heavily subsidises his business to make it more accessible to the 'small pockets' of his clients. The free Government Hospital rarely has doctors or drugs and the private clinics are prohibitively expensive.

11.5 Conclusion

A novel ranking approach has placed the bacterial zoonoses brucellosis and BTB at the bottom of the list of cattle diseases recognised by the KGR community. Hanta, a dual aetiology condition (liver fluke +/- black disease) and trypanosomiasis are perceived by the community as the two priority diseases of cattle. The KGR community currently spend more on prophylactic treatment for cattle than they do on human health. Overall, the household expenditure on human and animal health is low and reflects the relative poverty of this community. Fevers in people are prevalent in this setting and self-medication is the first line approach. Community perception is that fevers are due primarily to malaria and typhoid. Community education could go a long way to improving community approaches to animal and human health. Overall, the KGR community have demonstrated good knowledge of cattle disease conditions, treatment approaches are adequate for most diseases, but the block treatment of animals with antibiotics raises concerns. Knowledge of small ruminant and human health conditions was found to be poor in comparison. Community access to veterinary services is very poor, but availability of human health services is thought to be adequate by the KGR community. Diagnostic capacity of the private and NGO clinics is unfortunately very limited. The return of Dr Jamo, a highly qualified medical doctor, has gone a long way to improving community health and it would be interesting to quantify the impact.

12 Chapter 12 Evaluation of system's approach

This chapter deals with the evaluation of the system's or One-Health approach to disease control tested in this thesis. For conclusions on socioeconomic profiling and animal and human health in KGR refer to specific chapters.

12.1 Multiple disease approach

12.1.1 Bacterial zoonoses cluster approach

The ICONZ project approach for delivery of parallel intervention packages - incorporating a cluster of diseases - to communities was tested for the bacterial zoonoses cluster in the KGR. Addressing bacterial zoonoses (anthrax, BTB and brycellosis) collectively had mixed success: i) anthrax, although endemic, is only observed during outbreaks and cannot be investigated simultaneously to cross-sectional surveys for BTB and brucellosis; ii) simultaneous testing for brucellosis and BTB, despite requiring two household visits, is feasible and cost-effective (see 12.2); iii) collective control measures targeting the animal reservoir may not be appropriate as culling of TB reactors is not acceptable in the pastoralist context (see 12.2) and iv) control measures targeting the human population through education on avoidance of risky behaviour may offer a low cost strategy for reducing human burden, however this approach still requires validation.

12.1.2 Host species approach

This work demonstrates the added value of research into same host diseases. Data on four cattle diseases (brucellosis, BTB, helminths and trypanosomiasis) were collected during three surveys. It is beyond the scope of the thesis to report the exact costs of fieldwork in the KGR. This figure, however, is predicted to be roughly equivalent for a single versus multiple disease approach as gaining access to the community is the more costly component of the overall cost. Multi-disease assessment promotes economies of scale as a single study multiples research outputs by the number of diseases investigated.

12.2 Diagnosis and control tools

While brucellosis and BTB are 'diagnostic-tool ready', only brucellosis and anthrax are 'control-tool ready' for use in a resource-poor country.

This work has demonstrated that cheap and robust tests can be used under the most difficult of field conditions in a pastoralist community. The RBT was proved to be a good test even under field conditions, both for the diagnosis of animal and human brucellosis. All brucellosis serological tests, however, require validation under local conditions (see Chapter 7). The SICCT for the diagnosis of BTB was demonstrated to be appropriate even in the absence of animal tagging using a novel identification system effective under wet season conditions. The parallel diagnosis of brucellosis and BTB in cattle was found to be feasible despite requiring two visits to the same household three days apart. The advantages to this approach include: i) the livestock keeper can be informed of results both for brucellosis and TB during the second household visit; and ii) milk samples for brucellosis bacteriology can be collected from animals found to be seropositive. Information transfer to livestock keepers raises awareness of disease situation, which if complemented with health messaging could encourage behaviour change promoting reduction in brucellosis transmission. Bacteriology is vital as different *Brucella* species (and potentially strains) vary in their zoonotic potential.

Integrated control of brucellosis, BTB and anthrax in the animal reservoir is currently not feasible in KGR. Vaccines for brucellosis and anthrax exist and could be administered in parallel, but there are barriers to implementing mass vaccination (see Chapter 10). Until an effective BTB vaccine is developed, the prospects for BTB control in pastoralist communities remains bleak as test and slaughter is not a culturally acceptable option nor economically feasible if livestock keepers cannot be compensated for the full value of culled livestock.

For brucellosis, there may be opportunities for better vaccines to be developed based on *B. abortus biovar 3a*, which is hypothesised to be less virulent (see Chapter 8). The current vaccines of choice are currently S19 for cattle and Rev1 for small ruminants and have demonstrated improved safety and reduced serological interference by conjunctival administration. Pastoral systems often do not have

calving seasons increasing the risk of vaccinating pregnant animals and resulting in animal infections with vaccinal trains and potential transmission of vaccine strains to humans (which are resistant to some of the antibiotics routinely used for the treatment of field strains of brucellosis). The livestock keeper knowledge of individual animal pregnancy status should be sufficient to prevent vaccination of gestating animals. Veterinarians must administer *Brucella* vaccines. In the absence of quality government or private veterinary services in KGR, the delivery of a vaccine campaign is currently unsustainable unless this gap is filled.

An appealing and low cost strategy for the control of brucellosis and BTB in KGR is health education and messaging, as described in Chapter 10. Whilst this approach is unlikely to result in a detectable impact due to the very low baseline burden of disease in KGR, piloting of locally adapted education campaigns in an alternative community with a higher burden of brucellosis and BTB would be of value.

Dealing with multiple diseases is complex and difficult to manage; the challenges associated with a single disease are multiplied by the number of diseases investigated. This is especially true in surveillance-vacuum zones where nothing is known about disease presence or absence or general epidemiology. This study has revealed that assumptions about disease characteristics in an area can be wrong, leading to 'unexpected' challenges which require troubleshooting. This is probably one of the reasons why vertical and single disease approaches prevail: it is easier to untangle evidence for one disease and reach solid conclusions. The added-value of generating evidence for multiple diseases with one intervention cannot be underestimated and while this approach is associated with challenges, this work has demonstrated that such challenges can be overcome through synergy.

12.3 Case study approach

The ICONZ Case Study approach in Nigeria failed to identify communities at higher risk of co-morbidity. Despite assumptions that pastoralist communities constitute the main sufferer and reservoir of brucellosis in Nigeria, evidence from this small-scale study in KGR suggests otherwise. However, the geographical limitations of this study means that findings cannot be extrapolated to pastoralist systems in general in Nigeria without further studies in other settings.

Indeed risk factors need to be studied on a wider scale, incorporating humans and animals, intensive and extensive livestock production systems, in different geographical settings (urban versus rural) and ecological, epidemiological and socioeconomic contexts, with the objective of successfully identifying and targeting at-risk groups for high priority interventions. As discussed in Chapter 6, the lack of surveillance data or good quality epidemiological studies (prevalence and incidence) remains an impediment to the recommendation and adoption of human and animal brucellosis control in this country. Only then can experiences and pilot interventions from separate initiatives in different geographical and epidemiological contexts be evaluated for extrapolation and/or amplification.

12.4 Parallel, multi-host approach

The value of the multi-host approach is being able to quantify the impact of the disease in the animal reservoir as well as the human population, without which erroneous epidemiological conclusions may result. For example, presence of brucellosis in cattle in KGR, paradoxically, was not reflected by presence of human disease. A study investigating brucellosis in the animal reservoir only could have led to incorrect assumptions about human burden of disease and unsuitable recommendations for control.

In this specific context there is no ‘dual burden’ of brucellosis. By definition One Health only applies where disease affects both animals and humans. In this case there are no human benefits of animal interventions, and cost-sharing across the human and animal health sectors is not justifiable as benefits are limited to animal health. In the absence of human cases there is no human involvement and brucellosis becomes a veterinary issue which does not require a One Health approach.

This unexpected finding is in fact very good news for the pastoralists of the KGR with one less problem facing this impoverished community. Improvements in animal and human health should now be focused on other diseases with a greater impact on the community. This work has shown that brucellosis control measures should be targeted elsewhere, particularly the intensive commercial livestock production systems or in settled smallholder livestock keepers.

12.5 Interdisciplinary approach

Moving away from disciplinary silos to a more holistic or systems approach spanning epidemiology, evaluation of diagnostic and control tools, and examination of socioeconomic, cultural and institutional aspects, whilst more complex, can yield more robust recommendations about culturally and context appropriate interventions. The systems approach adopted here incorporated investigation of barriers to health and veterinary care in the impoverished, marginalised KGR, to define the role of isolation, population movements or migration, social and political unrest, and conflict on welfare. Participatory and social science approaches are a cheap way to investigate the impact of zoonoses in communities as well as offering sustainable, culturally appropriate and inexpensive solutions to disease control. The findings of Chapter 11 show that community perception of disease is not always accurate, highlighting the importance of complementing such evidence with robust epidemiological data. This is an important conclusion at a time when community epidemiology is a popular approach gaining momentum.

12.6 Community approaches

The success of this work was based on extensive community sensitisation to project aims. The importance of community involvement extends to interventions. In Chapter 10 recommendations are made about health messaging campaigns designed for the KGR community. A community-led approach may be the solution to ensure sustainability and affordability of such schemes.

12.7 'Neglected' for a reason?

This present work failed to find evidence of brucellosis in people in the KGR. Certainly for the KGR community, evidence from Chapter 11 on human and animal health suggests that non-zoonotic diseases such as malaria and typhoid in humans, trypanosomiasis, helminthiasis and clostridial disease in cattle and PPR in small ruminants may be having a much bigger impact. Further studies would be necessary to confirm priority diseases in terms of burden for the community. The low burden of brucellosis compared to malaria in the KGR, however, suggests that brucellosis may be justifiably 'neglected' in humans in this context.

12.8 Association with poverty

In KGR, however, poverty appears to be more of a risk for human-specific and animal-specific diseases rather than for zoonoses categorised under the bacterial zoonosis cluster. The hypothesis of an association between traditional production systems and brucellosis and BTB due to occupational exposure of pastoralists has not been shown to apply in KGR. Brucellosis is hypothesised to be more of a problem in settled and/or intensive commercial systems.

12.9 Brucella abortus biovar 3a

Brucellosis epidemiology varies depending on both host and pathogen factors: circulating *Brucella* species and strain, and presence of ruminant host species. Findings from this study are specific to circulation of *Brucella abortus* biovar 3a in an extensive, transhumant pastoralist community and cannot be extrapolated to differing epidemiological contexts. Differences between *Brucella* species and strains may explain differences between this system and that of *B. melitensis* small ruminant systems where human disease is a huge problem due to the higher pathogenicity of this species to humans or cattle systems with a burden of *B. abortus* biovar 1 or *B. abortus* biovar 3b. For the same reasons, control strategies used in Europe for control of *B. abortus* biovar 1 and *B. abortus* biovar 3b may not be appropriate for the *B. abortus* biovar 3a context due to differences in epidemiology.

The distribution and extent of *B. abortus* biovar 3a is currently unknown, for Nigeria, the wider West African region and for sub-Saharan Africa as a whole. We also do not know if other areas and/or ruminants in Nigeria harbour more virulent strains of greater zoonotic potential such as *B. melitensis*. Further epidemiological and bacteriological studies are key to addressing these gaps in evidence.

12.10 The economic argument for control of bacterial zoonoses

In the absence of human disease it was not possible to calculate the societal burden of disease or demonstrate cost-effectiveness of animal interventions for the prevention of human disease. Before societal burden of brucellosis or BTB can be calculated for Nigeria, we must elucidate: who is affected; what is the impact; where are the affected people and animals, etc.? When those questions have been answered

we can address: how much is the disease costing to society: how much does it cost to control and what are the benefits of control?

Productivity was not found to be statistically significantly different between brucellosis positive and negative herds. The low number of seropositives made interpretation of impact on productivity unrewarding and further studies (e.g. longitudinal studies) collecting data on productivity parameters in brucellosis infected and free pastoralist herds are required.

Unfortunately without an economic argument there is currently no advocacy for control of bacterial zoonoses based on the evidence of this thesis.

12.11 Political upheaval and the future of pastoralism and prospects for control of bacterial zoonoses

This work in northern Nigeria was undertaken at a time of growing political upheaval. Prospects for brucellosis control seem bleak in the current climate of ethno-religious crises, acts of Muslim-extremist terrorism (Boko Haram), clashes over competition for land-use, growing discontent at the widening disparity in wealth between the North and South and struggle for political supremacy (see Chapter 3).

In this climate of instability, the future of pastoralism as it currently exists also seems uncertain, as illustrated by this statement from an elderly Ardo (chief) from KGR during a key informant interview on what the future holds for his children: *'I want my children to live a life where they can grow enough to support their animals during the dry season. There is no future in sending animals into the wilderness. The future for nomadic style pastoralism is bleak. If we do not learn how to grow crops for our own consumption and forage, the big farmers with big farms will remain only and nomads will be boxed out of their livelihoods.'*

His sentiments were echoed by the president of the Dairy Bull cooperative of the KGR: *'Our transhumant system as we know it is going to face a lot of problems. The livestock population is increasing whilst the graze-able land is decreasing, which encourages competition of crop farmers with pastoralists. The crises are forcing Fulani to migrate to crisis-free areas. We used to have abundant grasses but as a result of the crises there is more migration of people and increases in the population*

of the grazing reserve. This has resulted in an increased population density of livestock per graze-able areas. If this continues, pastoralism and nomadism will have to stop. Agreeing to stop transhumance will take a long time, as most movements are to look for greener pasture otherwise our animals would starve.'

This man then went on to offer his vision of the only solution for the Fulani issue in Nigeria: *'I appeal to the government to let there be grazing reserves like the KGR in all states of Nigeria. This will go a long way to curtailing the farmer pastoralist conflict. KGR has never had a crisis, as there is no competition with native men unlike in other states. The grazing reserves, apart from helping to solve the problems of the crises, have the added advantage of giving the Fulani man a right to ownership. Let the Fulani man have land that he owns.'*

These statements show that there is increasing pressure, both societal and political, for migratory Fulani to settle - in reserves and elsewhere - and adopt farming practices used by indigenous people.

The migratory pastoral livestock, despite acting as a reservoir of brucellosis currently may not require substantial disease control measures if consistently presenting with low disease burden. The evolution of livestock systems from extensive (subsistence) to intensive (settled and more commercial) systems within a complex political climate and lack of veterinary and public health capacity may provide the ideal conditions to trigger outbreaks of brucellosis - with huge impact on productivity and public health. The settling of Fulani offers political solutions and greater access to a dairy market chain but increases brucellosis risk with informal milk value chain consumers increasingly at risk of brucellosis.

Further studies investigating these different disease systems are essential to understand and quantify risks in the emerging livestock sector and the different pathways towards mitigation of its impact on the poor.

It is likely that strategies for brucellosis control need to be tailored to specific livestock production systems. Transhumant pastoralists may require only integrated social and public health education measures. In terms of policy recommendations this may appeal as veterinary disease control programs across these extensive migratory populations are difficult to implement, while access to settled herds is

more straightforward. Both settled pastoralist and indigenous populations could be targeted for vaccination, especially where there are efforts to develop the milk, meat and hide value chains. Control of brucellosis in these emerging livestock systems is more amenable to a vaccination strategy that could be supported by veterinary and medical public health policy.

The problem of brucellosis emergence in a context of livestock intensification is not a political priority in the current climate of increasing tensions and conflict, and the scientific evidence to promote this livestock production system tailored approach is not yet available. Political upheaval is concurrently a driver for emergence and a barrier to finding solutions to this threat.

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